ASTRONOMY

March 1980
$2

The Cooling Fire of Creation

Death of the Space Age

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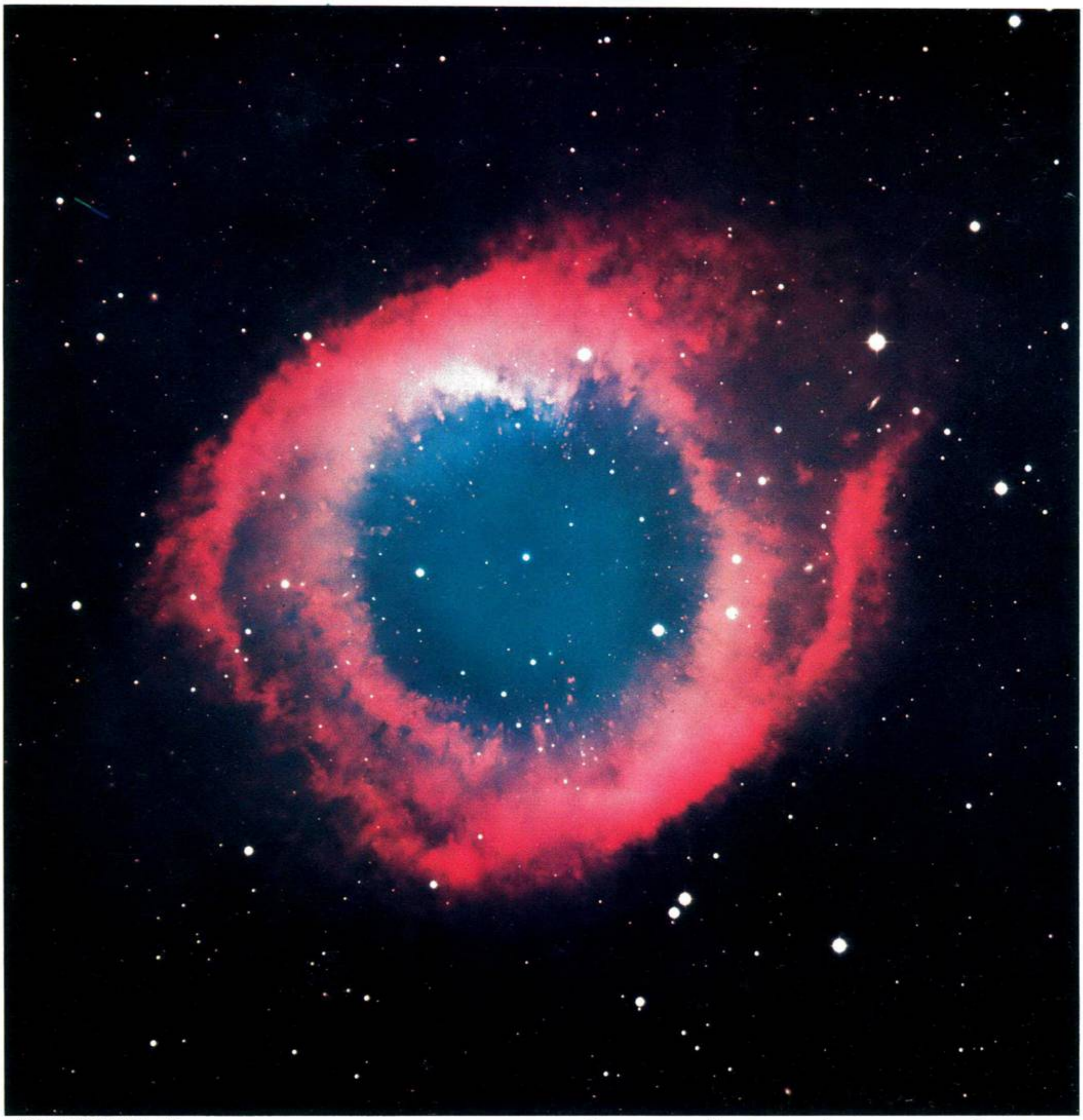

The Colors of Deep Space

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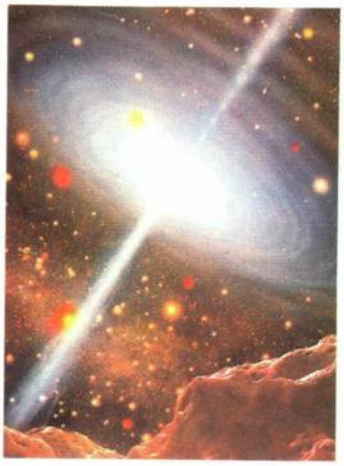

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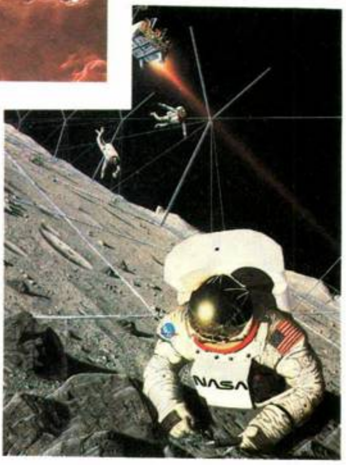

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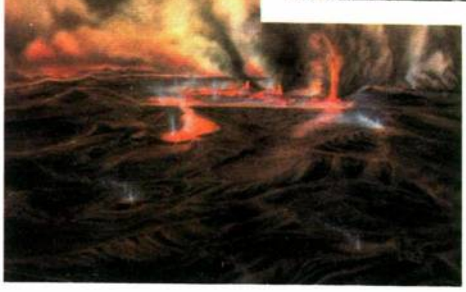

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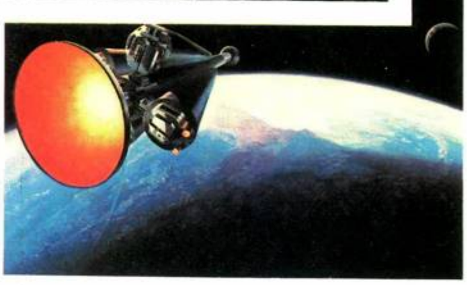

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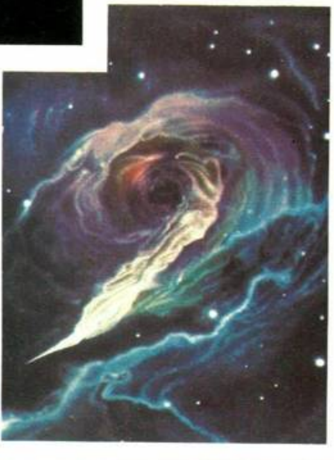

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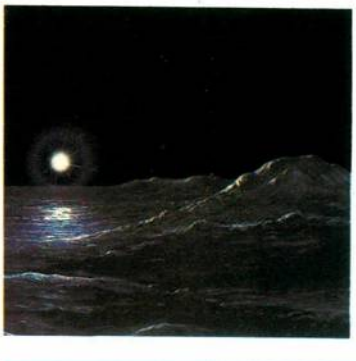
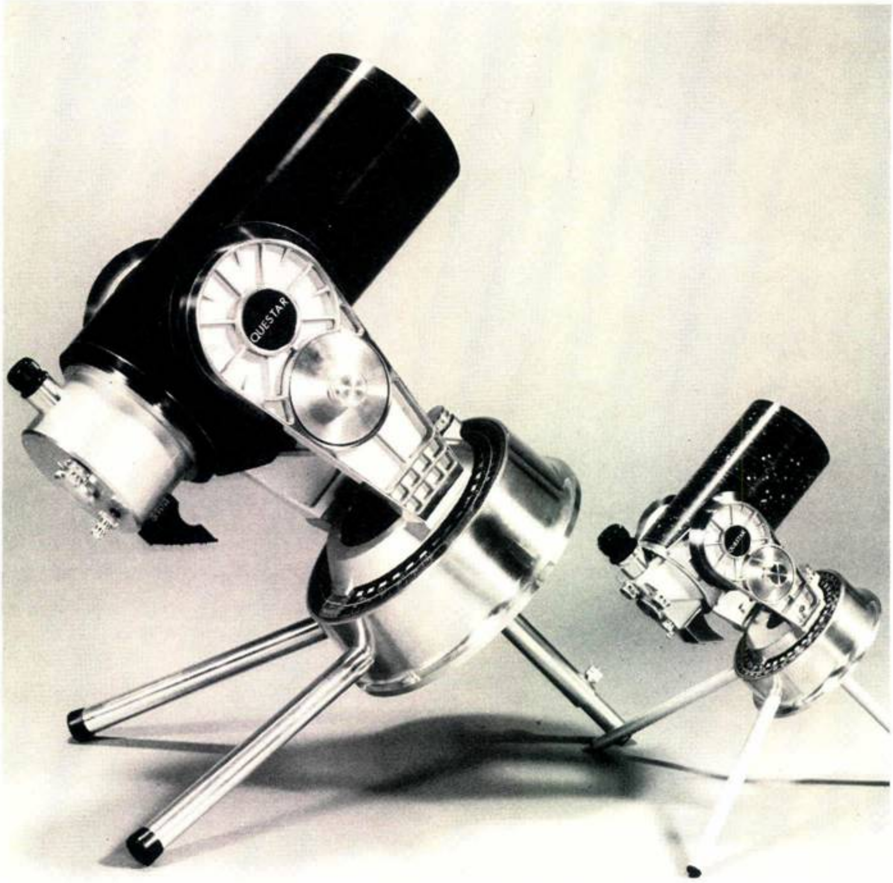


Please order posters by name and artist on the form between pages 60-61.

FOR THE LOVER OF FINE INSTRUMENTS . . .

the Questar family of telescopes

©Questar Corporation, 1977, 1980



Because Questar's inventor loved fine instruments, he designed Questar for himself. He had begun dreaming about the kind of telescope he someday wanted to own, long before such a thing was considered a possibility.

To begin with, of course, there was to be a set of optics so fine that no amount of money, time, or human effort could improve upon it. Second, since he believed that the use of a telescope should not be a difficult physical chore, the size was extremely important: it should be easily portable. Preferably it would be small enough to be used on a table, where a person could sit in a relaxed position to observe and be able to have a writing surface at hand. And since he planned to carry it in his travels, it would be packaged handsomely in a piece of leather luggage.

Third, the accessories which were necessary for the enjoyment of a telescope were to be built in and should have fingertip controls within easy reach.

Fourth, the mechanical design must incorporate a means of putting the telescope into its polar equatorial position at a moment's notice and without the need of a separate tripod.

Fifth, the versatility that he visualized would make this instrument equally suitable for nature studies in the field. It also should be able to focus on close objects, which no other telescope in the world could do.

Sixth, the design must be photovisual so that he could record on film whatever these superior optics would present to the eye.

And finally, the instrument must be of rugged construction and vibrationless, without the aggravating oscillations of long-tubed conventional telescopes.

* * *

As we have said, this was the dream, but one lacking the possibility of fulfillment within the state of the art at that time. However, in the 1940's an important discovery in optics occurred. When Maksutov published, in the *Journal of the Optical Society of America,* a paper on his mixed lens-mirror, or catadioptric, system, it was immediately apparent to Questar's designer, Lawrence Braymer, that this break-through in optics would make possible a miniaturized version of the astronomical telescope which he had for so long wanted to build.

The Questar telescope reached the market in 1954: 3.5 inches of aperture with a 7-foot focal length in a sealed tube only 8 inches long, and with all the built-in conveniences that he had planned. These included a wide-field finder, power changes without changing eyepieces, smooth manual controls in altitude and azimuth, safety clutches, setting circles, a sidereal clock, and synchronous motor drive. Moreover, a totally safe solar filter had become an additional feature created for the solar observer.

Included, also, were legs for a tabletop polar equatorial position; and as the design had progressed it had come to include two other conveniences: a map of the moon anodized on the barrel and a chart of the stars anodized on an aluminum sleeve to slip over the barrel. The chart revolves for monthly star settings and slides forward to serve as a dewcap. Both charts make other maps unnecessary during observing sessions.

Most remarkable of all were the optics—this was a system so fine that it has consistently delivered resolution surpassing its theoretical limits. Throughout its subsequent history, the care and precision with which every set of optics has been made and star tested has earned for the Questar telescope its reputation as the finest in the world.

* * *

Other Questars have followed over the years—the Seven, which is twice the size of its world-famous predecessor, has twice the resolving power and four times the light grasp; and more recently, the Questar 700. The latter is an f/8 telephoto lens for the photographer, and *Modern Photography* has simply called it "the best." The 700 guarantees perfection and flatness of field from edge to edge; also, precise focusing from infinity to 10 feet with a single turn of the focusing ring.

A newcomer to the fleet is the Questar 12, which is Questar Corporation's answer to the problem of an important telescope for the university and for special industrial applications, as well as the ultimate in a personal telescope.

We always say that when you buy a Questar telescope you get the whole observatory. For example, the 3 1/2 in its fitted case contains all that you need to enjoy the earth or skies, day or night. Your Questar need never be idle, and you can carry it with you wherever you go. In a recent letter a Questar owner called it "an enchanting companion."

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6 **The Colors of Deep Space**
by David Malin

14 **The Cooling Fire of Creation**
by Barry Parker

Forum **24** **The Death of the Space Age**
Messier Marathon

Sky Almanac **30** **The Opposition of Saturn**

Photography in Astronomy **39** **Photographing the Sun**
by James Felbab

Equipment Atlas **47** **Building a Sundial**

Gazer's Gazette **53** **Estimating Magnitudes**
by Raymond E. Zit

Astronomy Reviews **56**
AstroNews **58**

Stellar Frontiers **67** **The Radio Universe (1)**
by Clarence H. Annett

In Focus **72**
Behind the Scenes **73**
AstroMart **74**
Star Dome **80** **Western Hydra/Antlia/Pyxis**

In the depths of space lie objects of great beauty unveiled for the first time in all their grandeur by a combination of innovative photographic techniques developed in Australia. This month's cover features the Helix Nebula (NGC-7293) in Aquarius. The detailed enlargement of the same object on this and the facing page reveals the delicate structure and shading recorded by David Malin's tricolor process. Photograph copyright © 1979 Anglo-Australian Telescope Board. Also in this issue of ASTRONOMY we explore the cooling fires of creation, take a look at the techniques of modern radio astronomy, and show you how to photograph the Sun and use its light to tell time by building your own sundial.

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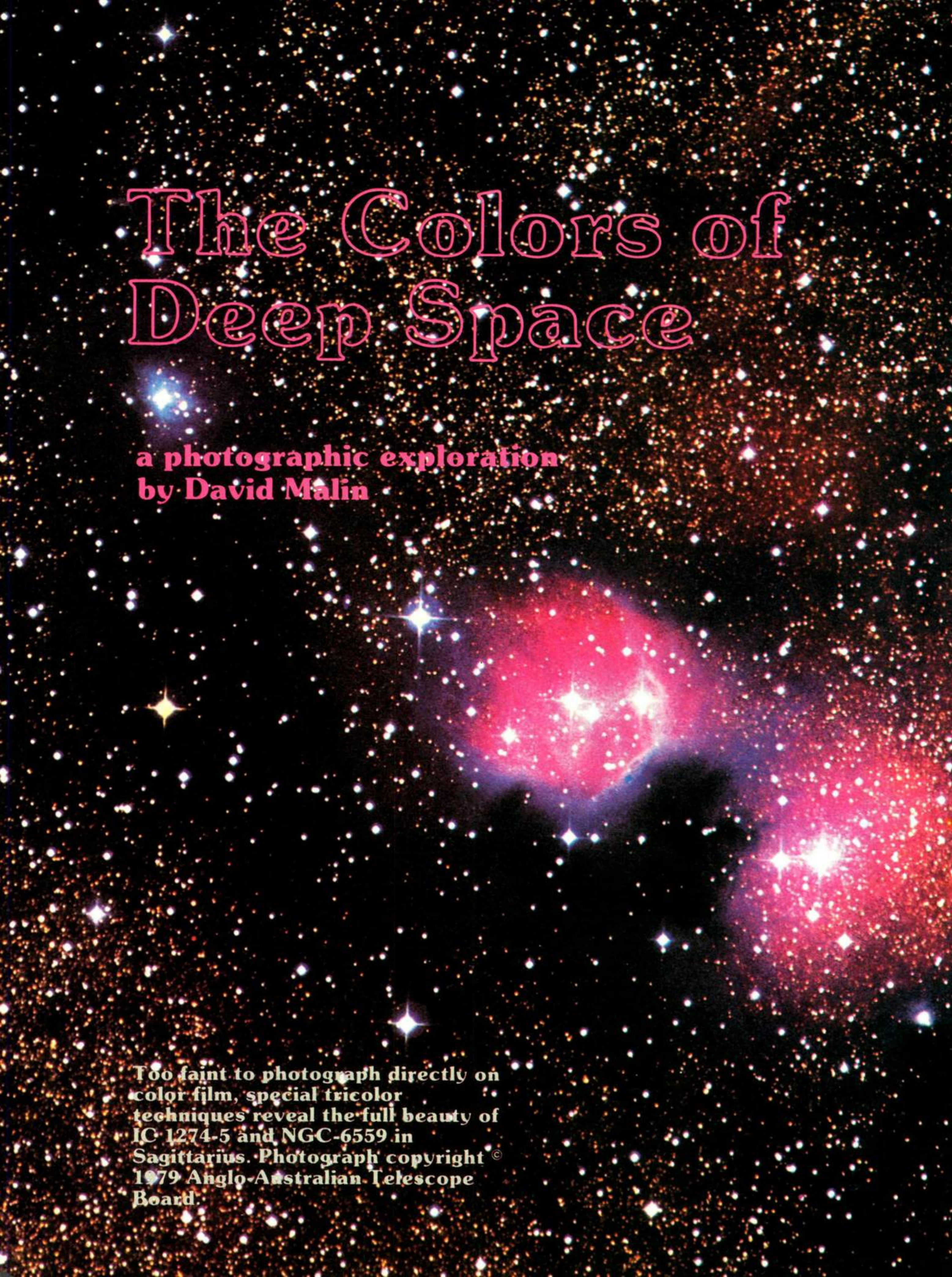
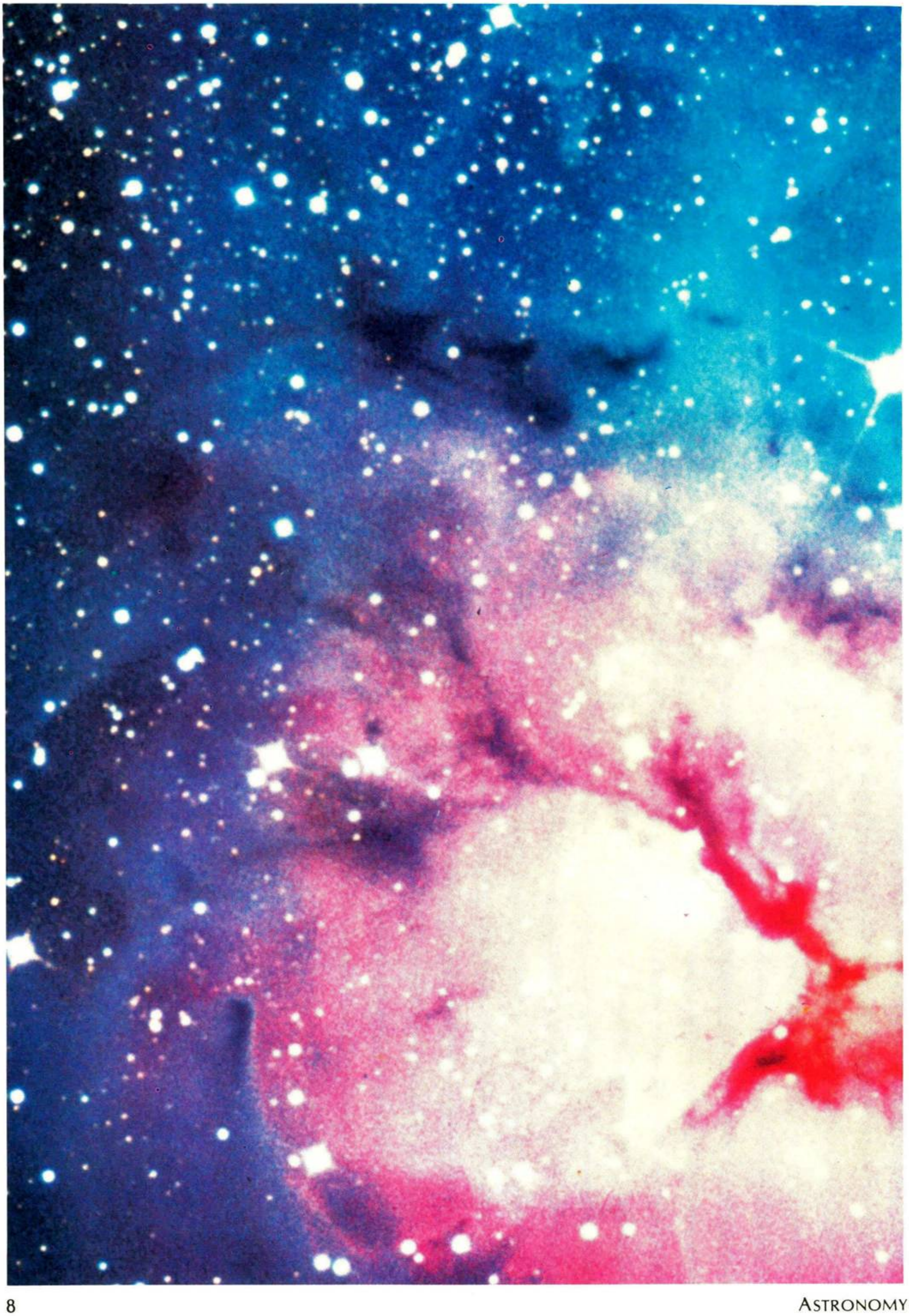
The Colors of Deep Space

a photographic exploration

by David Malin



Too faint to photograph directly on color film, special tricolor techniques reveal the full beauty of IC 1274-5 and NGC-6559 in Sagittarius. Photograph copyright © 1979 Anglo-Australian Telescope Board.



Designed for making pictures by reflected sunlight at the bottom of our atmosphere, commercial color films are able to reproduce the full range of colors and contrasts found in the average scene in an entirely convincing way. Unfortunately, the peculiar demands of astrophotographers were not part of the design specifications for these materials. It is remarkable, therefore, that they serve so well in an application for which they were not intended.

A basic problem — due entirely to the nature of the objects being photographed — restricts the usefulness of today's color films to the more luminous inhabitants of the night sky. Much of the light which reaches us from celestial objects comes at very specific wavelengths, in very narrow but intense lines of the spectrum. These narrow bands of energy (emission lines) are particularly strong in the clouds of ionized gas which are ideal candidates for color photography. Hydrogen, the most abundant element in space, is responsible for the deep red color of so many astronomical pictures, and color films respond well to this part of the visible spectrum. However, ionized hydrogen, together with other elements (notably oxygen), also radiates strong blue-green lines in a part of the spectrum where color films are at their least sensitive, and their colors appear weakly (if at all) in conventional color pictures of emission line objects.

Color Pictures from Black and White Plates

This problem can be overcome by taking separate black and white photographs in blue, green, and red light and combining them in the lab to make a color picture. (See "Tricolor Astrophotography," ASTRONOMY, December 1979.) Careful selection of plate and filter combinations ensures that there are no significant blind spots in the visible spectrum and that the response within each color band is fairly uniform. Of course any three plates can be added together in any three colors to produce a color picture, but accurate color rendition is only possible if the three regions of the spectrum recorded on the original plates are reproduced in the final picture with the same relative intensity and contrast — and, of course, in register.

The following combinations of Eastman-Kodak spectroscopic plates and Schott glass filters are used to record the blue, green and red parts of the spectrum:

- Blue: IIaO plate + GG 385 or 395 filter
  (3850 or 3950 - 5000 Angstroms)
- Green: IIaD plate + GG 495 filter
  (4950 - 6300 Angstroms)
- Red: 098-04 plate + RG 630 filter
  (6300 - 7000 Angstroms)

Choice of filter defines the short wavelength limit of the sensitive region of the spectrum, and the spectral sensitization of the emulsion determines the long wavelength limit. This upper limit is a more gradual fall in sensitivity than that given by a filter and results in an overlap between the end of one spectral region and the start of the next. This is important for the correct reproduction of intermediate colors such as the blue-green and orange-red hues.

It so happens that the three plate/filter combinations we used correspond closely to the standard photometric colors used in astronomy, and a set of plates suitable for color photography is also valuable for quantitative photometric work — which can be a useful advantage when applying for telescope time for color pictures! Hypersensitized spectroscopic plates are a good deal more efficient than color films at recording faint light and show little or no reciprocity failure. The brighter nebulae (such as the Orion and Eta Carinae) require only a few minutes exposure, and sky-limited plates for the faintest subjects are obtained in 30-40 minutes with an f/3 telescope. Color separation plates can even be taken in bright moonlight using narrow-band interference filters centered on the OII, OIII and Hα or SII lines found in many gaseous nebulae. Like the broad-band photometry plates, these interference filter negatives are valuable in their own right, and it is likely that many suitable sets of plates already exist within the astronomical community just waiting to be combined into useful and beautiful color images.

Adding is a Positive Process

There are two basic ways of making a color picture from color separations. The most direct approach is to print the three negatives separately but in register onto a negative-working paper. The blue, green, and red plates are printed through yellow, magenta, and cyan filters respectively onto any normal color print material (such as Ektacolor paper). With this kind of subtractive printing, the color and density of the sky background are critically dependent on accurate matching of both the exposure and contrast of the original plates — the slope of the three characteristic curves must be identical. Mismatched originals will make it impossible to obtain consistent color balance across the full tonal range of the print. A further difficulty is the high contrast of the originals which limits the dynamic range obtainable on the final prints.

An alternative procedure, and the one adopted here, is to make contact positive copies of the original three plates and print them through their corresponding filters onto a positive-working print material (such as Cibachrome). In this method, the positive from the red plate is printed through a red filter to give the red image, the green positive through a green filter, and so on. This system is known as additive printing and is in many ways superior to the more direct, subtractive method. The chief merit of the additive process is its flexibility. Using positive copies, it is possible to match the characteristic curves of the three plates quite accurately over most of their density range. This is especially important with the emulsion types used for this work — the 098-04 plate is much more contrasty than the IIa types, and uncorrected this would give some rather peculiar red/green color shifts. As well as equalizing the

The detailed view of a part of the Trifid Nebula (M-20) seen opposite reveals the extent of blue-green reflection nebulosity surrounding the red hydrogen alpha emission. The complex structure of dark absorbing clouds lying between us and the nebula is clearly visible in this tricolor photograph made from three separate plates. Photograph copyright © 1979 Anglo-Australian Telescope Board.

contrast of the plates, contrast can also be lowered overall to give prints with a much wider dynamic range than is possible with the direct process.

The contrast manipulation methods described in an earlier article ("Exploring the Image," ASTRONOMY, November 1979) all produce their results as positive contact copies which can be used to make color pictures. Both unsharp masking (to increase the dynamic range) and photographic amplification methods (to reveal the faintest objects) yield derivatives from which stunning full-color pictures can be made without further treatment. It is clear that the simple extra stage of making a positive intermediate gives a color process of enormous flexibility where both contrast and color balance can be adjusted to meet the very special requirements of astrophotography.

Color Balance

A neutral color in the picture to guide color balance is very important. Nowhere is this more important than in astronomy where the "correct" subjective colors are quite unknown. In the prime focus camera of the 3.9-meter (150-inch) Anglo-Australian telescope, we have installed a small projector which images a faint step-wedge on the edge of the plate. This calibration exposure is controlled by the camera shutter so that both sky and step-wedge exposures pass through the same filter onto the same plate for the same time. These calibration spots, which are also the basis for accurate determination of effective exposure times, appear on all AAT plates and are carried through all copying processes to appear in the final color prints. They serve as a check on color balance, dynamic range, and parallelism of the three characteristic curves. The telescope calibrator is adjusted to give a neutral grey step-wedge, its tungsten light source being filtered to reproduce mean noon sunlight.

The next stage in obtaining color balance occurs in the enlarger. It, too, must be adjusted to print a neutral grey onto color paper. Quite simply, a neutral step-wedge is printed successively through red (Wratten 25), green (Wratten 58), and blue (Wratten 47B) filters onto a positive-working color paper to give a neutral print. This establishes the ideal exposure ratios for a perfectly matched set of color separation positives. With Cibachrome A paper and a tungsten lamp, the red:green:blue ratios will be about 1:2:3 and an ideal set of color separations will require exposures of (say) 10, 20, and 30 seconds to reproduce the neutral plate step-wedge as a true neutral. Small variations in telescope exposure and processing of the separation positives will necessitate adjustments, but if the telescope wedge is reproduced exactly as it should be, then all the other colors in the photograph will be subjectively correct.

Apart from some refinements and the use of modern materials, this method of additive color photography is identical to the tricolor method demonstrated by the great physicist James Clerk Maxwell in 1861. He superimposed three positive transparencies onto a screen simultaneously to produce a full color image, but he had no means of preserving it permanently. In the method outlined above, the three images are registered in sequence on color photographic paper. Accurate registration is of course an important facet of this technique.

The Photographs

This method of making color pictures, especially when combined with the photographic amplification techniques described in ASTRONOMY's November 1979 article, produces results of scientific importance as well as aesthetic beauty.

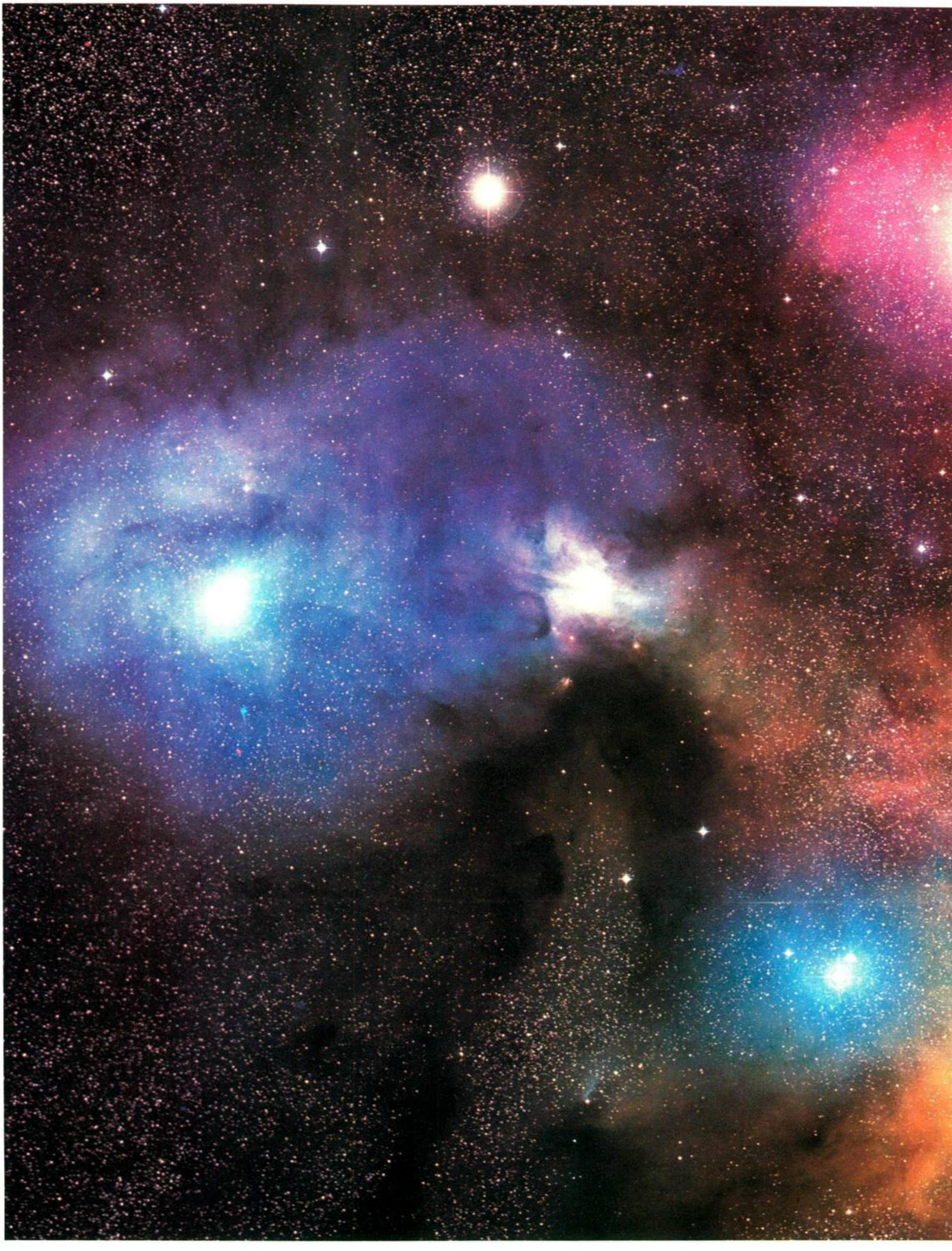
The central stars of planetary nebulae are characterized by their extremely high temperatures evident in the large amounts of ultraviolet radiation they emit. Near the central star, this radiation is sufficiently intense and energetic to ionize the tenuous remnants of oxygen and nitrogen thrown off by the star as it formed the planetary nebula. Farther away from the star, the radiation is less intense and less energetic (due to absorption), and the brilliant red of hydrogen recombination emission appears. Where green and red occur together, they give rise to a yellow color. All these colors are seen in the picture of the Helix Nebula (NGC-7293), a color picture made from plates taken on the 3.9-m Anglo-Australian telescope. The changing energy levels can be traced outward from the central star by observing the green-yellow-orange-red color sequence. The blue-green plates were taken consecutively on the same night and an asteroid trail, changing from blue to green, can be seen at upper left in the cover picture. There is no red asteroid because the red plate was taken over a year earlier as part of another project.

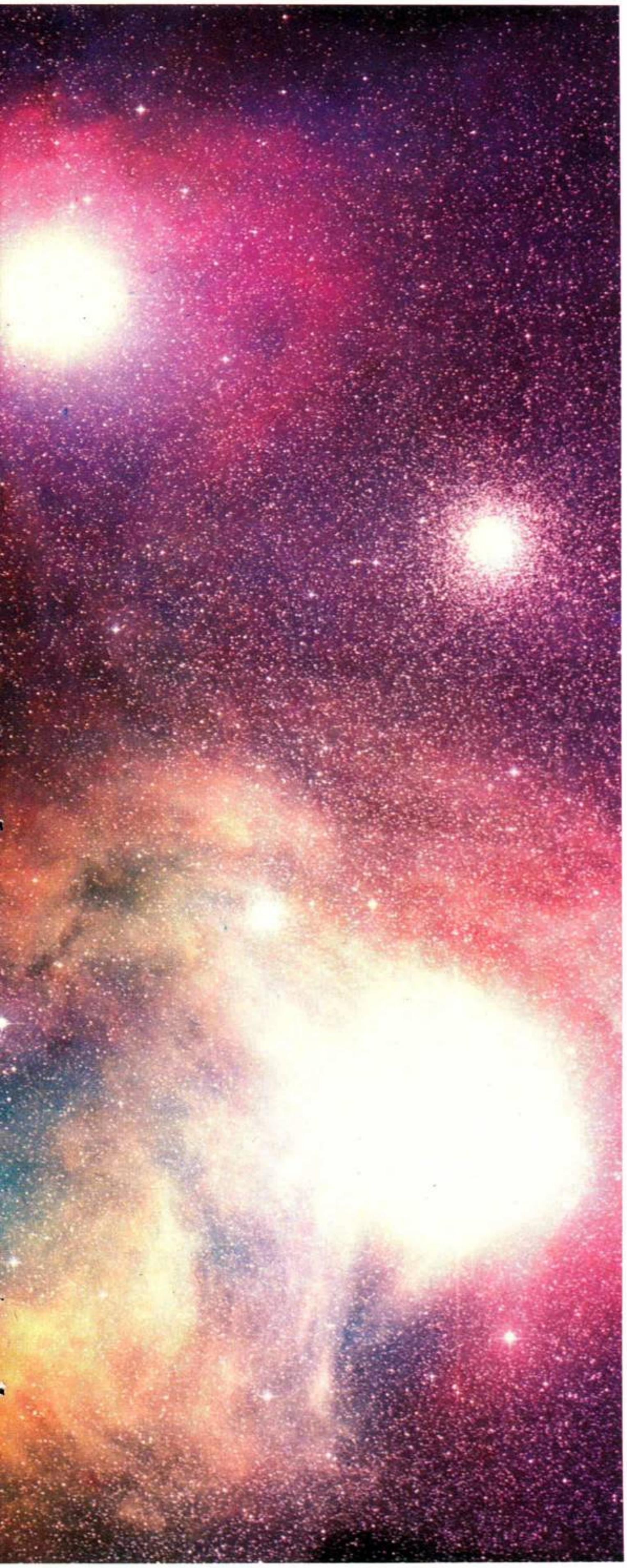
Quite nearby in the sky and associated with a complex mixture of gas and dust which includes both M-20 and the larger M-8 (Lagoon Nebula), lies a smaller and much fainter group of objects containing IC-1274-5 and NGC-6559, too faint to produce a satisfactory image on color film. The full beauty of this object is only revealed by applying photographic amplification techniques to the three original plates. A sinuous dark lane of dust crosses a region of red hydrogen alpha emission and the whole area is surrounded by obscuring material, some of which reflects blue starlight. Behind the dust, around the edges of the picture, can be seen a backdrop of yellow population II stars which form the more distant parts of the Milky Way.

The picturesque Trifid Nebula (M-20) is a spectacular combination of red hydrogen alpha emission associated with a large patch of blue-green reflection nebulosity. This picture reveals that the bluish glow of reflected starlight extends all around the red region and can be seen extending out of view. This is probably the deepest color picture ever made of this beautiful object.

The first of this new generation of color photographs to be produced was the Vela Supernova Remnant. This faint but very large object extends over an enormous part of the southern sky and is associated with an even larger emission region known

The tangled red wisps of the Vela Supernova Remnant stand out against a background of pale blue nebulosity, first detected on this tricolor image. The supernova which gave rise to this beautiful nebula exploded between 6000 and 12,000 years ago, and may have been observed by primitive cultures in ancient Egypt and Mesopotamia. The Vela Pulsar itself, a relatively young neutron star, is not visible here. Photograph copyright © 1979 Anglo-Australian Telescope Board.





The brilliant colors of deep space are revealed as never before in this wide-angle view of the region around Antares and Rho Ophiuchi. The entire region is actually spanned by an enormous dark cloud of obscuring gas and dust, and it is against this background that these colorful formations are seen. Antares is at lower right, with the nearby globular cluster M-4 immediately above. Rho Ophiuchi itself is at left center. Photograph copyright © 1979 Anglo-Australian Telescope Board.

as the Gum Nebula. It glows by the light of protons and electrons, recombining after being split asunder by an enormous explosion 12,000 years ago. This same explosion left behind a rapidly-rotating neutron star, the Vela Pulsar, too faint to be seen on our photograph which was made from three plates taken with the 1.2-m U.K. Schmidt telescope. The predominant red color was expected but the diffuse blue glow, associated with but separate from what appears to be the leading edge of the expanding cloud, came as something of a surprise. The blue rim can be seen most clearly in and near the bright red nebulosity to the north (left) and west (top) of the photograph on page 11. This discovery, made as a direct result of this method of deep-color photography, is being followed up spectroscopically by us with the 3.9-m Anglo-Australian Telescope.

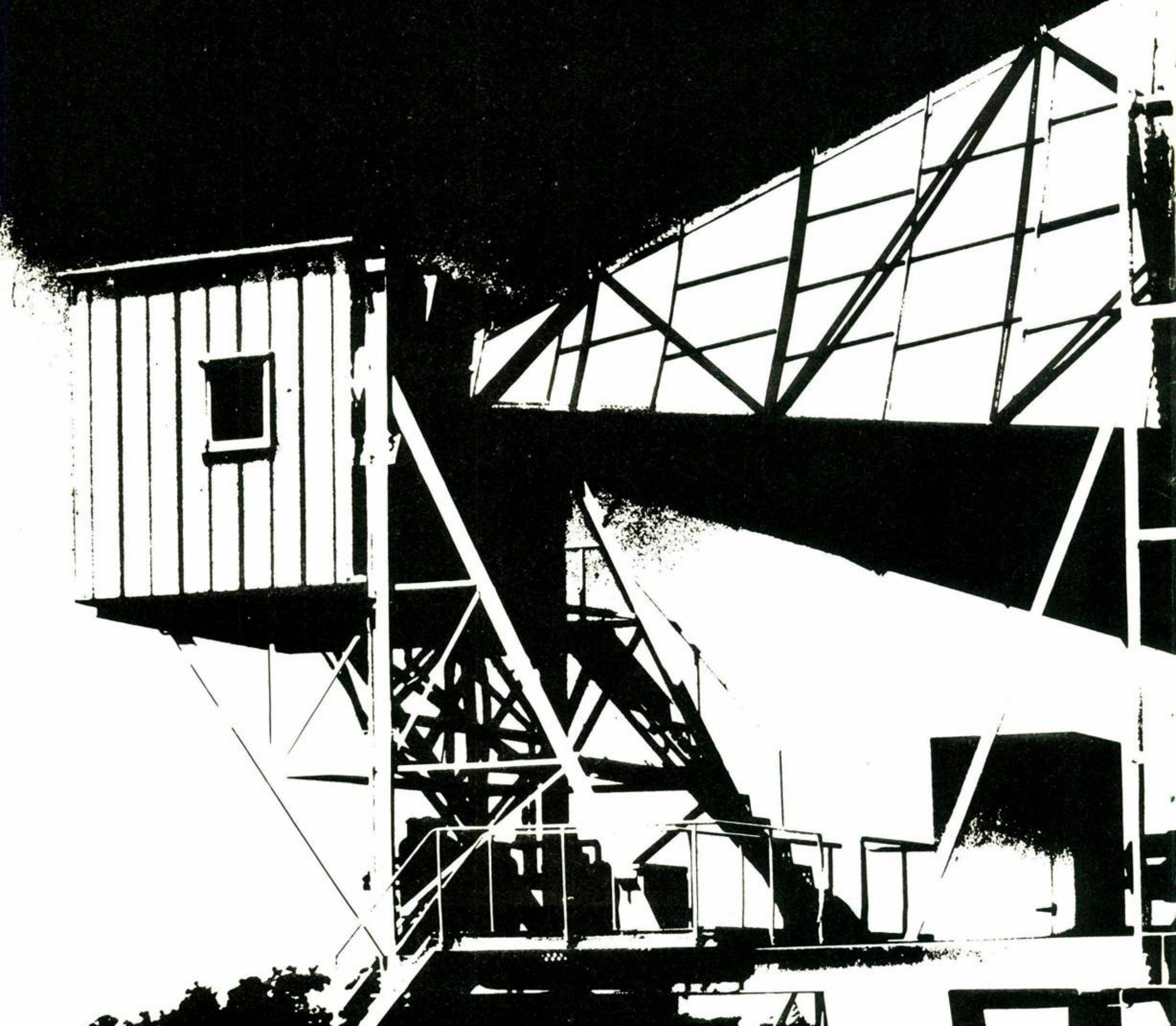
An enormous swath of obscuring gas and dust, spanning large regions of the constellations of Scorpius and Ophiuchus, passes almost overhead to observers in Australia. This dark cloud, large because of its relative proximity (about 700 light-years), contains one of the most colorful collections of objects in the sky. The field shown in the image and indeed the whole of the dark cloud, is named after Rho (ρ) Ophiuchi, the bright star embedded in blue reflection nebulosity (left center in the photograph). The full extent of the nebulosity is revealed for the first time in color in this composite made from three plates taken with the 1.2-m U.K. Schmidt. About 1° to the south of Rho, another rather red star illuminates more of the same cloud, and blue-green reflection nebulosity surrounds the $4^{m}.9$ star 22 Scorpii to form IC-4605 at bottom center. By far the brightest object in the field is Antares, Alpha Scorpii, a 1.2 magnitude star embedded in yellow and red nebulosity. Above the fiery Antares is the globular cluster M-4, at 5700 light-years away the nearest globular cluster, considerably dimmed by absorption of its light in the dark cloud. Above and to the left of M-4, a wisp of brilliant red nebulosity can be seen surrounding Sigma Scorpii.

Though this is referred to as a region obscured by a dark cloud, a fact made obvious by the patchy distribution of the background faint stars, the field is not absolutely dark. This sky-limited color picture reveals a faint brownish-yellow haze over most of the upper part of the picture, turning to a yellowish-red in the region around M-4 and Sigma Scorpii. Only one small region near the center of the photograph is devoid of emission or reflection. Only here can the Rho Ophiuchi Cloud be described as truly dark.

Thus a method of color photography first demonstrated over a hundred years ago can today be employed to great effect. The brilliant and colorful pictures reproduced here only hint at the possibilities inherent in this old yet new process.

The Cooling Fire of Creation

by Barry Parker



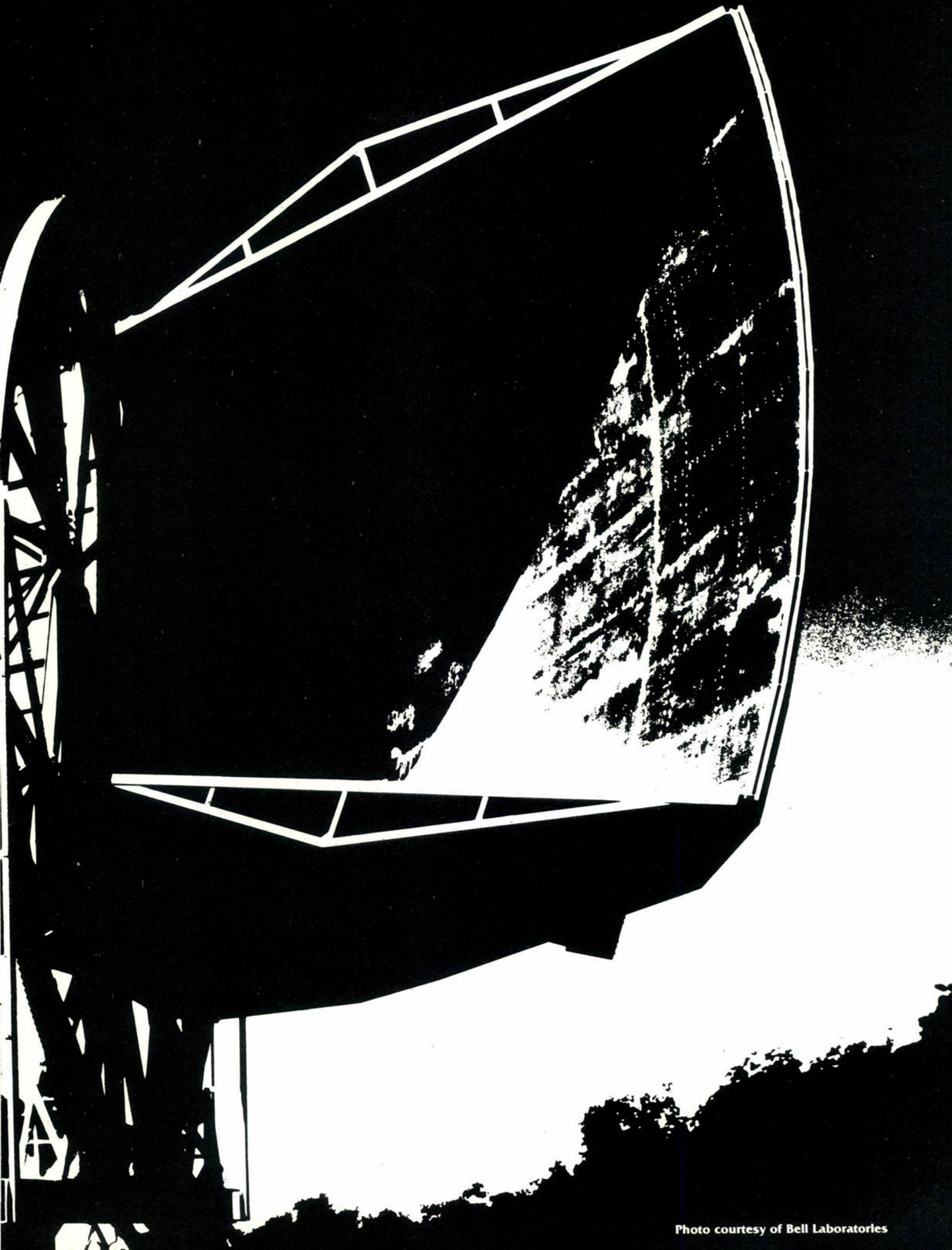


Photo courtesy of Bell Laboratories

What does it take to make an important scientific discovery? Most scientists would probably tell you hard work, perseverance, considerable patience — and a little luck. Indeed, all of these are important. But sometimes the most important thing is recognizing the discovery when you've made it. Many important discoveries have no doubt been made and overlooked because someone didn't recognize the significance of the results. The planet Uranus, for example, was sighted a number of times by observers who failed to recognize it as an undiscovered planet. The famous discovery of the cosmic background radiation was almost such a case.

In the early 1960s the first Telstar satellite was put into orbit. Signals were to be reflected from it to a radio telescope on a hilltop near Holmdel, New Jersey. But this was no ordinary radio telescope. Most radio telescopes have a large dishlike antenna; this one looked more like an oversized alpine horn. And, unlike most antennas, it was solid so it could "catch" waves of relatively short wavelength: microwaves.

The two scientists assigned to the instrument, Arno Penzias and Robert Wilson, soon realized that the instrument was ideal for radio astronomy. Once they completed their work with Telstar they could use it to study microwave emissions from our galaxy, radio waves with wavelengths shorter than those previously detected. In fact, they would likely have this wavelength range all to themselves, for this was the only large telescope of its type in the world.

Their first task was to identify and eliminate any low level extraneous noise the instrument might be picking up. Noise of this type can be caused by many different things: the atmosphere, surrounding objects, and perhaps even the antenna itself. They started with what they thought would be a relatively quiet wavelength — 7.35 centimeters — but to their surprise they detected much more noise than they expected. They adjusted and checked everything carefully, but it just wouldn't go away. Could it be the antenna? Pigeons had been wintering in it, it seemed, and had left a layer of white "residue." Perhaps that was causing the problem. They cleaned it thoroughly and taped the joints carefully, but nothing seemed to help. They began to get irritated. How could they ever study the radio emission from our galaxy if they couldn't get rid of all this noise?

By chance, Penzias had discussed the noise problem with a physicist in Boston who told him of certain work going on at Princeton University (also in New Jersey). Unknown to Penzias and Wilson, two scientists at nearby Princeton had just predicted the existence of such a noise. Robert Dicke and James Peebles had shown that radiation left over from the Big Bang explosion should still fill the universe. Furthermore, it should be detectable in a radio telescope as a low-level signal. Dicke encouraged his colleagues Roll and Wilkinson to search for it. They had barely started, however, when Dicke received a telephone call from Penzias.

The seed had been planted, fertilized, and watered. Could this be the radiation the Princeton scientists had predicted? A quick trip to Holmdel soon convinced Dicke that it was. It had all the characteristics of the radiation he and Peebles had predicted. Penzias and Wilson were no doubt quite relieved. The two groups decided to publish simultaneously; Penzias and Wilson would announce the discovery and Dicke, Peebles, Roll, and Wilkinson would give their interpretation in an accompanying paper.

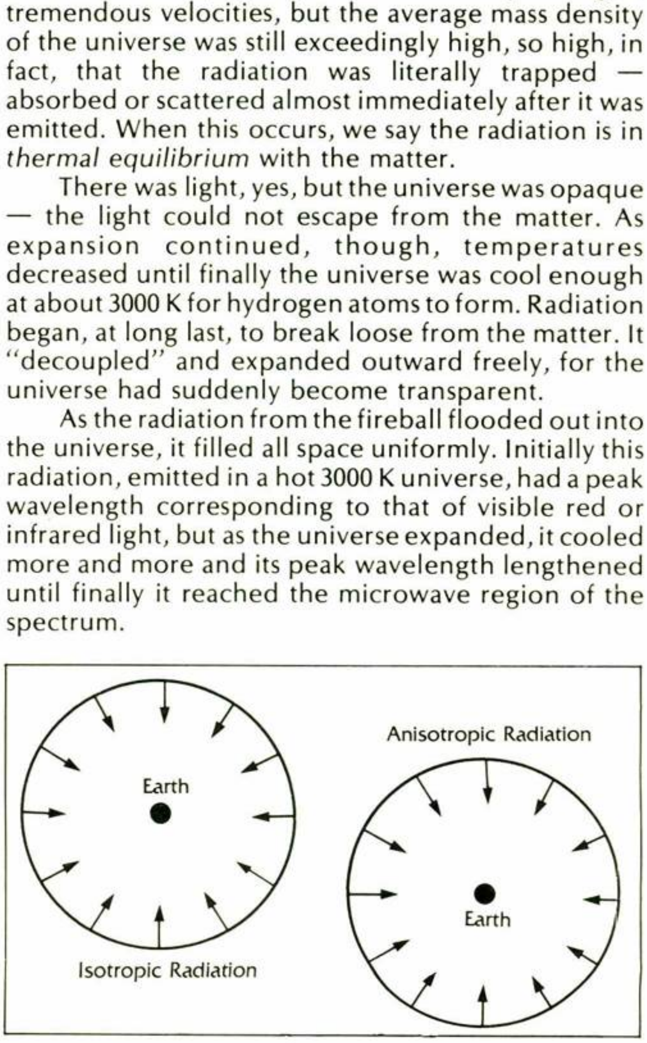
But not everyone greeted the announcement with cheers of delight. In fact, the interpretation by Dicke and his colleagues literally shocked three people — for they had already made the prediction 17 years earlier. In a series of papers beginning about 1948 George Gamow, Ralph Alpher, and Robert Herman had shown that there should be a residual radiation in the universe with a temperature of about 5 K (it was originally predicted by Gamow to have a temperature of 25 K). Gamow was therefore furious when he saw that Dicke's paper made no mention of their earlier estimate. He rushed a letter off to Penzias telling him of the prediction, pointing out in particular that it had been repeated several times. He had even included it in his popular book *The Creation of the Universe*.

The Origin of the Cosmic Background

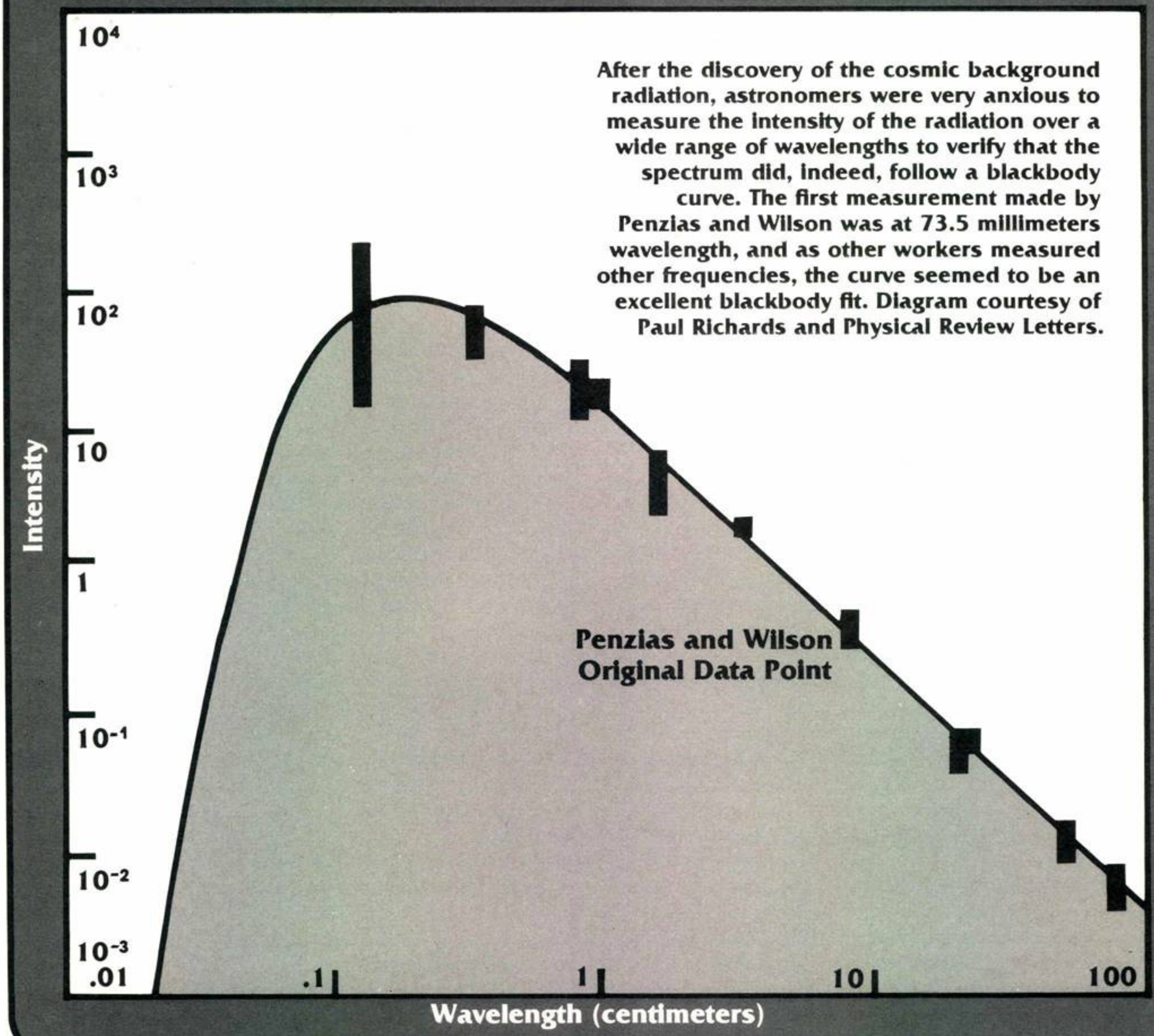
But why has the discovery of this radiation caused such a stir in the world of astronomy? What exactly is it? And why is it all around us now? To answer these questions we must take an imaginary trip back in time to the Big Bang explosion. For hundreds of thousands of years after the explosion, the universe consisted of nothing but particles and radiation (and perhaps a few black holes). The particles were separating at tremendous velocities, but the average mass density of the universe was still exceedingly high, so high, in fact, that the radiation was literally trapped — absorbed or scattered almost immediately after it was emitted. When this occurs, we say the radiation is in *thermal equilibrium* with the matter.

There was light, yes, but the universe was opaque — the light could not escape from the matter. As expansion continued, though, temperatures decreased until finally the universe was cool enough at about 3000 K for hydrogen atoms to form. Radiation began, at long last, to break loose from the matter. It "decoupled" and expanded outward freely, for the universe had suddenly become transparent.

As the radiation from the fireball flooded out into the universe, it filled all space uniformly. Initially this radiation, emitted in a hot 3000 K universe, had a peak wavelength corresponding to that of visible red or infrared light, but as the universe expanded, it cooled more and more and its peak wavelength lengthened until finally it reached the microwave region of the spectrum.



Measuring the Cooling Fire



After the discovery of the cosmic background radiation, astronomers were very anxious to measure the intensity of the radiation over a wide range of wavelengths to verify that the spectrum did, indeed, follow a blackbody curve. The first measurement made by Penzias and Wilson was at 73.5 millimeters wavelength, and as other workers measured other frequencies, the curve seemed to be an excellent blackbody fit. Diagram courtesy of Paul Richards and Physical Review Letters.

As we look out into the universe today we see this radiation coming to us from all directions. Looking closer we see it is almost exactly *isotropic* (equally strong from all directions). In other words, the radiation reaching us now in effect started out in a shell surrounding us. This is the shell of last scattering, the shell in which the decoupling took place. It is important to remember that this decoupling occurred in the very early stages of the universe — almost 20 billion years ago. This means that this shell is now moving away from us at near the speed of light. What effect does this have? We know that visible radiation (ordinary light) from distant galaxies suffers a Doppler shift toward the red end of the spectrum (see "The Redshift Problem," ASTRONOMY, September 1978 for an explanation of the Doppler effect). Its wavelength is "stretched out," or lengthened. The wavelength of the fireball radiation will also be stretched out, or "cooled," by the expanding universe in the same way.

It should be pointed out that this radiation has a particularly important property. When it was emitted, the universe was only about 500,000 years old, which means that the fireball radiation is the most ancient signal that now reaches us. And, of course, as we look outward we are looking back in time. But this radiation comes from far beyond the outermost galaxies — even beyond the quasars. Beyond everything. As the lingering echo of the Big Bang itself, the cooling fire of creation, it truly is the background of the universe, and for this reason it is usually called the *cosmic background radiation.*

The cosmic background radiation has now cooled to about 3 K — at only three degrees above Absolute Zero, it's a very cold fire indeed. What do we mean when we say that radiation has a certain temperature? First it is important to note that all objects above Absolute Zero (0 K) radiate, or taking a more modern point of view, we say they emit photons. (Absolute Zero is, incidentally, the lowest possible temperature in the universe. At one time it was thought that outer space was at this temperature.) If we take a black box and cool its interior to 3 K, there will be a certain number of photons in thermal equilibrium with the 3 K inner walls. A radio telescope placed in this box will receive a message — a kind of hissing or static — which is caused by these photons. This is the three degree signal. If we increase the temperature of the box to, say, five degrees, we will get a slightly different signal — the five degree signal. Five hundred degrees will produce a five hundred degree radiation signal, and so on.

But even though Penzias and Wilson had detected a low level signal, how could they know for sure that it was caused by the cosmic background radiation? Fortunately, there is a good test: the intensity of thermal radiation depends on its wavelength. If a plot of wavelength against intensity is made, the curve will have a certain characteristic shape. This shape can be compared to a standard which is obtained by heating a "totally absorbing" object called a *black body* and plotting its intensity curve. If the theoretical and observed curves agree, then it's likely the radiation does actually come from the early universe.

Let's look a little more closely at this theoretical blackbody curve. Starting at the long wavelength end and moving toward the shorter wavelengths, we find the intensity slowly increases. Eventually, though, the curve peaks, and beyond this point it falls off rapidly. For a temperature of about 3 K, the peak occurs at a wavelength of about two millimeters. And, as it turns out, this is the critical region for the background radiation.

The first few points obtained, including the one by Penzias and Wilson, were all on one side of the peak. But would the intensity fall off and conform to the curve beyond this peak? This was an important question in the mid-sixties. You might think astronomers could simply have gone out, taken a few quick measurements, and seen. Unfortunately, it's not quite that easy. At wavelengths below about two millimeters our atmosphere becomes a problem, absorbing those wavelengths. We must therefore get above it with rockets or balloons.

The first check on this region showed an excess of radiation; the point did not lie on the curve. Scientists were worried. Maybe this wasn't the cosmic background radiation after all. The work continued, however, and soon several groups had verified that the curve turned over as it should. Finally, in 1976 a group at the University of California extended the data down to exceedingly short wavelengths. The results seemed to be conclusive: the radiation intensity *satisfied* the black body curve almost exactly. Scientists were excited — the radiation had to have come from the Big Bang.

What Does the Background Mean?

What is the importance of this radiation to us? It was important in settling the problem of the origin of the universe — it's a direct confirmation of the Big Bang theory. But of course it's much more than this. To understand one of its important implications, let's go back to the year 1887.

In that year a now-famous experiment was being set up in Cleveland, Ohio, by two Americans, Albert Michelson and Edward Morley. They were attempting to detect the Earth's motion through a medium called the *aether*.

Several years earlier light had been shown to be a wave which seemed to demand some type of medium to propagate it, just as a wave on a pond needs the water to propagate it. (Just try to imagine a wave in a dry pond!) So the scientists at the time assumed a propagation medium existed — which they called the aether. But it turned out to have some rather odd properties and, to top if off, presented us with a strange predicament.

To see what this predicament was, suppose you are out on a lake in a boat. You ask yourself: Am I moving? It's pretty easy to find out; just drop a weighted fishing line bobber overboard and watch it. If you drift away from it, you are moving. You can tell you are moving because the lake acts as a frame of reference with the bobber sitting at rest in this frame.

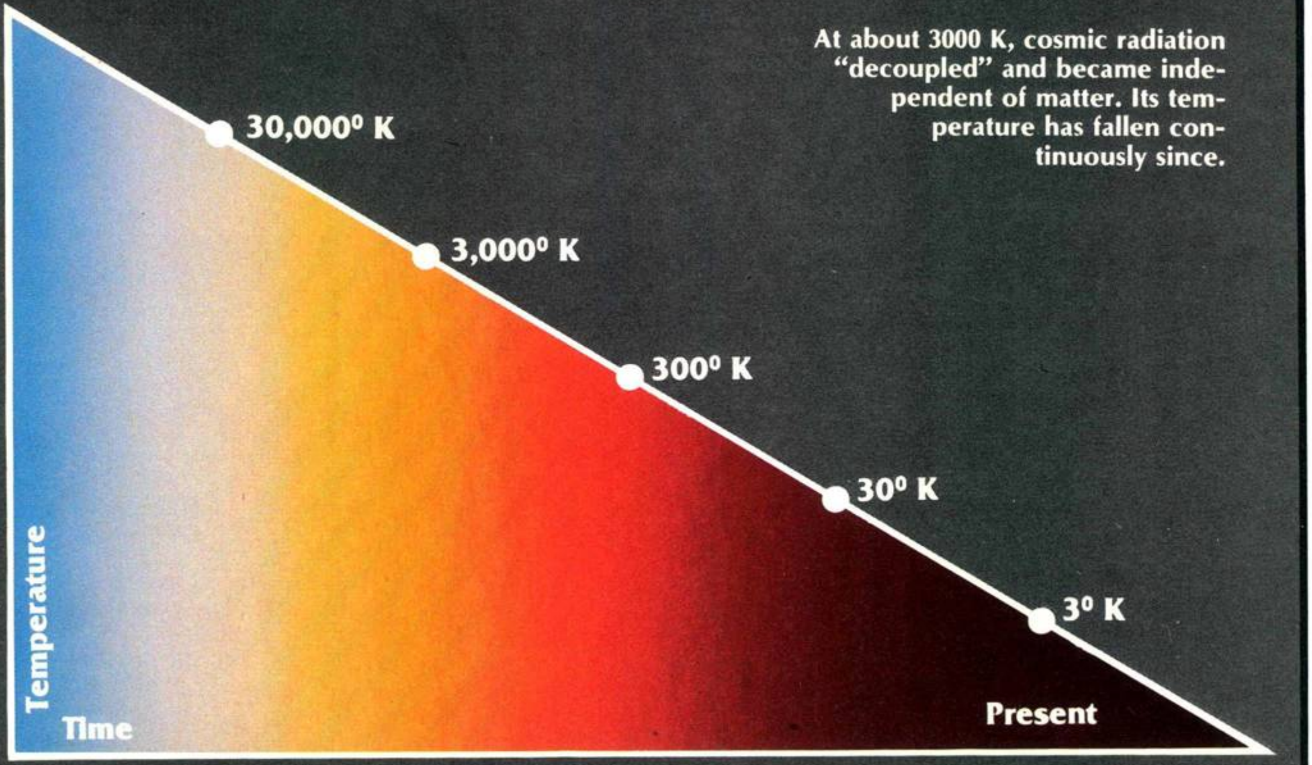
In the same way the aether as it was visualized in the 1800s could act as a reference frame for the universe. We should be able to determine how fast and in what direction we are moving through it. But when Michelson and Morley performed the experiment, they were amazed — the results indicated that we *weren't* moving relative to the aether. In fact a few years later Einstein showed that we didn't even need an aether to propagate light.

The aether (which was never really there anyway) therefore faded into obscurity, and with it went our chance to determine our velocity through the universe. Or did it? What about the microwave background radiation? It permeates the entire universe, and it gives us a background. It is, in a sense, as though we could use the shores of our dry, empty lake to measure our motion through it. We should be able, therefore, to determine our velocity relative to the background radiation coming from its distant shell. Scientists realized this soon after the existence of the radiation was established, and many began to talk about a "new aether experiment."

But how would we go about performing the experiment? How would we know which way we were traveling through it? Fortunately, there is a simple test: check the temperature of the radiation in all directions. Because of the Doppler effect, the radiation in our direction of motion will be slightly "hotter" than the average, and in the opposite direction it will be slightly "cooler." In fact there should be a cosine curve variation between the two points. Penzias and Wilson had already made some preliminary tests and had established that the radiation was isotropic to about one part in ten. In the mid-sixties Dave Wilkinson and Bruce Partridge of Haverford College set out to extend the data. They increased the accuracy to about one part in a thousand, and still the radiation was isotropic, perfectly even all across the sky.

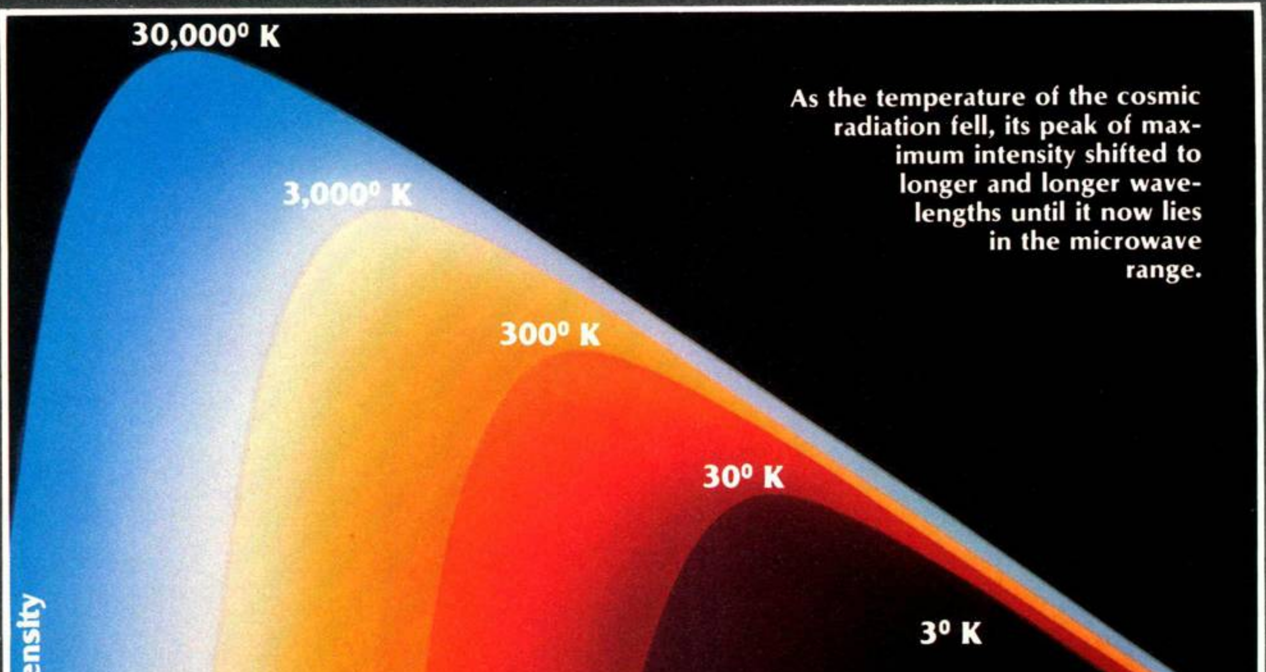
Was it possible to get higher accuracy? Surely there would be some unevenness — *anisotropy* — if we could. Two of the early experiments, one in 1969 by Edward Conklin and one in 1971 by Paul Henry,

The Cooling Cosmic Fireball

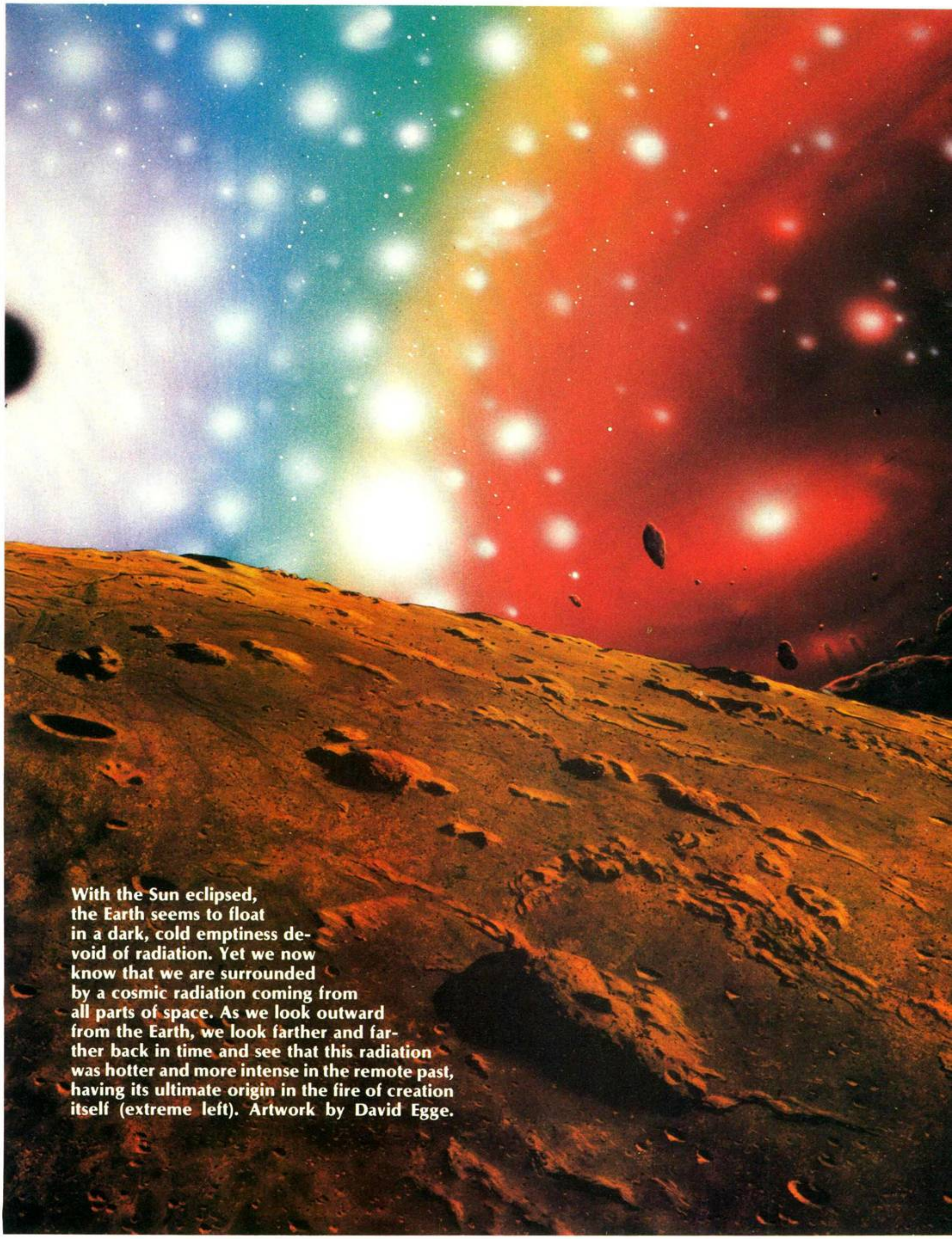

30,000° K
3,000° K
300° K
30° K
3° K
Temperature
Time
Present

At about 3000 K, cosmic radiation "decoupled" and became independent of matter. Its temperature has fallen continuously since.

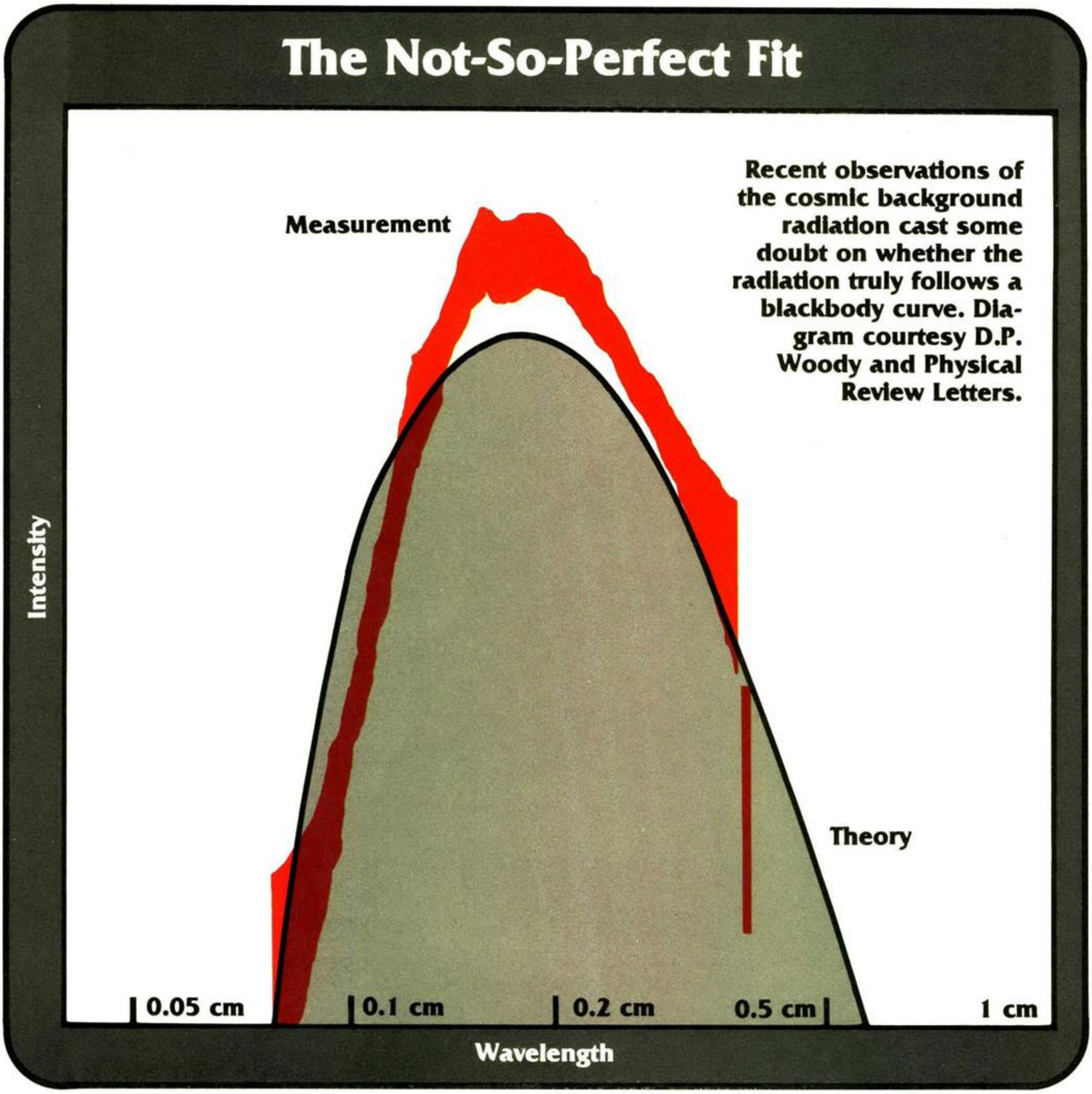
The background of radiation filling the universe declined in temperature as the universe expanded. Originally very hot, this cosmic radiation which fills all of space has now cooled to only three degrees above Absolute Zero. Artwork by Mark Paternostro.


30,000° K
3,000° K
300° K
30° K
3° K
Intensity
Wavelength

As the temperature of the cosmic radiation fell, its peak of maximum intensity shifted to longer and longer wavelengths until it now lies in the microwave range.



With the Sun eclipsed, the Earth seems to float in a dark, cold emptiness devoid of radiation. Yet we now know that we are surrounded by a cosmic radiation coming from all parts of space. As we look outward from the Earth, we look farther and farther back in time and see that this radiation was hotter and more intense in the remote past, having its ultimate origin in the fire of creation itself (extreme left). Artwork by David Egge.



The Not-So-Perfect Fit

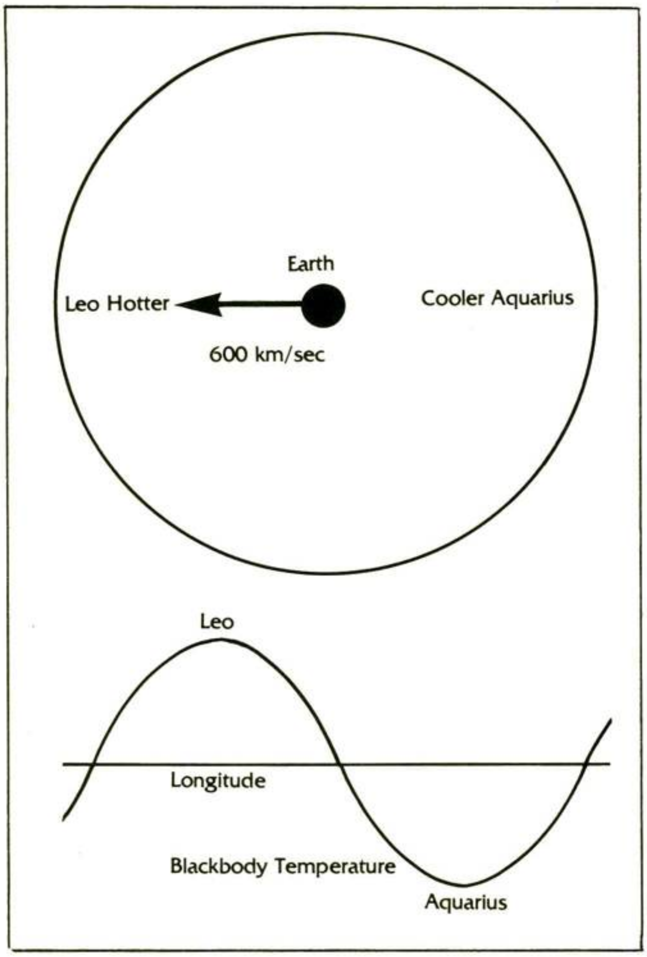
Recent observations of the cosmic background radiation cast some doubt on whether the radiation truly follows a blackbody curve. Diagram courtesy D.P. Woody and Physical Review Letters.

hinted at some anisotropy. But it soon became obvious that high altitude measurements were needed (to get above the water vapor in the atmosphere and to avoid various atmospheric emissions).

Two groups of scientists began making preparations. One group, consisting of Richard Muller, George Smoot, and Marc Gorenstein, was located at the University of California at Berkeley. They decided to enlist the services of NASA. A U-2 spy plane was available for flights at exceedingly high altitudes and this was exactly what they needed. The other group, consisting of Dave Wilkinson and Brian Corey, started out at about the same time in Princeton.

After about three years of preparations, Muller and his group were ready for their first flight. It took place in July 1976. Soon after the scan began, a variation was noticed. The intensity was maximum in the direction of the constellation Leo. Exactly opposite in the sky (in the direction of Aquarius) it was minimum, as expected, and indeed there was a cosine variation between the two points. Muller and his group were thrilled — but many months of checks and studies were still needed. Wilkinson and Corey obtained a similar result.

Our solar system is apparently moving through the background radiation at a velocity of 600 km/sec in the direction of Leo. (In making this calculation we must, of course, take into account the motion around our galaxy: about 300 km/sec.) Muller and his colleagues continued to study the results and soon found that not only is our solar system moving, but our entire galaxy is *moving in this direction*. *In fact* all the galaxies in a sphere of radius about 10 million light-years or so around us move in this direction.



Astronomers soon realized they had an important new tool. It could be used to verify the Big Bang theory and to find out how fast we're moving through the universe. And this wasn't all — many other things could be checked. One of the important questions we could now answer was: Is the universe spinning? This might seem like a strange question; after all, if the whole thing is spinning how could we possibly determine if it is spinning? A number of scientists believe we can. A simple test might be to project a particle outward in it. If the universe rotates, the particle will appear to be deflected.

There is an important principle in physics, known as *Mach's Principle,* which is closely associated with this problem. Mach's Principle states that local phenomena depend not only on nearby objects but on every bit of matter in the universe. If Mach's Principle is correct, we would not be able to determine if the universe is spinning or not. Muller and his associates decided to check the data for evidence of rotation. They found none.

Is the universe expanding in a lopsided way? Does it expand at different rates in different directions? There is some evidence that this might be the case. C. Rubin, W.K. Ford, and J.S. Rubin have looked at various types of objects (such as compact galaxies) known to have approximately the same absolute magnitude. If they are expanding away from us evenly in all directions, their intensity dropoff should be the same in all directions. For several types of objects, however, this isn't the case. Observations of these objects seem to indicate that some regions of the universe are expanding away from us at greater rates then others.

It might seem strange that our universe would be expanding in a lopsided way, but then why should it expand as a perfect sphere? Man has long looked upon the sphere as the most perfect solid shape, and it was logical to assume the Earth, Sun, planets, and stars were all spherical. It turned out, however, that none of these objects were perfectly spherical. Why then should the *universe* be perfectly spherical?

Measurements of the background radiation have not yet verified the lopsidedness found by Rubin and Ford. To investigate this problem, a special satellite will be put into orbit in 1983 (or soon thereafter). Aboard will be an apparatus that will allow us to test the background radiation to an exceedingly high accuracy. Perhaps it will give us the answer.

Astronomers may, in fact, detect much more than just lopsidedness when this satellite is sent up. Remember, the cosmic background radiation was emitted at an exceedingly early stage of the universe. It might therefore be able to tell us what conditions were like at this time. Was there any "clumping" at the time of decoupling? Astronomers suspect galaxies eventually formed as a result of clumping. If there was some, its signature would have been left on the surface of last scattering; we would see it as an tiny inhomogeneity in the radiation. Muller and his colleages didn't see any evidence of inhomogeneity...but perhaps in 1983.

Most astronomers believe that the radiation we are detecting is in fact from the Big Bang. But a few remain skeptical. Fred Hoyle of the California Institute of Technology thinks it could be starlight from other universes that border ours (see "Rival Cosmologies," ASTRONOMY, March 1978). As this starlight leaks into our universe, its wavelength is lengthened until finally we see it as microwave radiation.

Martin Rees of the Institute of Astronomy at Cambridge University has also shown that it can be accounted for in another way. If the universe were populated with huge, superluminous stars when it was exceedingly young — about 1-10 million years old — and if these stars were embedded in thick clouds of gas and dust, they could have generated enough radiation to account for the background we observe (see "Cosmic Microwave Radiation May Not Be Due to Big Bang," AstroNews, ASTRONOMY, April 1979). Rees assumed that the radiation was initially absorbed by heavy elements and molecules in the gas cloud and heated to a temperature of a few hundred degrees. This radiation would be redshifted in the same way as the background radiation from the Big Bang.

As interesting as they are, theories of this type are, of course, extremely speculative. Most scientists, however, still agree that the background radiation actually is the cooling fire of creation, and it also appears that this echo of the Big Bang will play an increasingly important role in astronomy. We may only have begun to tap its full potential.

Barry Parker is an associate professor of physics and astronomy at Idaho State University, where he teaches courses in descriptive astronomy, astrophysics, and cosmology. His main areas of interest are black holes and cosmology.

ASTRONOMY
FORUM

The Death of the Space Age

The Space Age is dying, killed by indifference, shortsightedness, and the Cosmic Isolationists. There are many people to blame: an indifferent President, a shortsighted Congress, a penny-pinching Office of Management and Budget, a disillusioned space agency.

But in the end the buck stops with us, the people who want the exploration of space to continue. In the wake of Vietnam, growing inflation, and the energy crisis, we find ourselves inarticulate, groping for ways to convince the American public and our leaders of the adventure and excitement of space exploration.

Science in the last few years, and space science in particular, has taken a savage beating. The public seems to have lost faith in the ability of science to solve the pressing problems of pollution, energy, starvation, and the threat of global war. Science is thought to be not a solution but the cause of our current crises. In the wake of Skylab, the lost RCA SATCOM satellite, and a faltering Space Shuttle, space exploration is no longer considered to be the first thrust of humankind into a glorious New Age, but a waste of time and money.

What happened? What went wrong?

For one thing, NASA has undergone an identity crisis. It started in the middle of the Apollo Moon landings ten years ago and it still continues. In the Sixties, the space agency had a clearly defined goal: to put a man on the Moon and return him safely to Earth. When it accomplished that goal, NASA suddenly found itself adrift.

It had a lot of projects on the drawing boards, many programs nearing activation, and a lot of dreams. But as the Seventies progressed, pressures from the public and Congress grew to put money into programs that would meet "down-to-earth" needs — the Vietnam war, the welfare system, the energy crisis, environmental concerns.

Many of those programs were indeed vital, and still are. Few deny the need to feed our poor and find them jobs. Few will quibble over the importance of cleaning our air and water. One look at the family heating bill will tell us the importance of finding alternative sources of energy.

> If we want to revive the Space Age, we had better learn how to do it: with good PR and by practicing canny politics.

But did Congress cut fat in government agencies? Did the politicians forego pork-barrel projects and a few "perks"? They did not. Rather, the legislators and a series of three Presidents heeded the cries of, "If we can put a man on the Moon, then we can..." They cut NASA apart like a butcher with a prize steer.

Former Vice-President Spiro Agnew didn't help things. He and a special committee in 1969 came out with a report calling for a 50-man space station, a manned Moon base, and a manned flight to Mars in 1985. The public hooted it down. "A waste of money!" they cried. "We put a man on the Moon; why can't we...?"

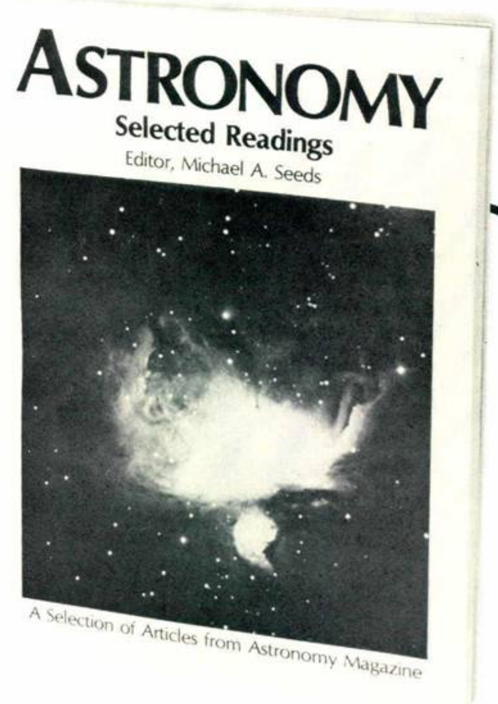
There was nothing wrong with any of those ideas; they're dreams many of us have had for years. But the timing was terrible and the PR even worse. NASA should have gracefully backpedaled, played it cool, and come up with a carefully designed program that would gradually build toward the eventual accomplishment of some of those goals. Instead, the agency rolled over and said, "Kick me some more."

The Cosmic Isolationists took the hint and roared to the attack. NASA lost its best brains, its imagination, and its nerve.

Ten years later, we can see the need for a major presence in outer space. Solar-power satellites could help alleviate our energy crisis. A large-scale move of industry into space could greatly reduce air and water pollution. Exploitation of the Apollo/Amor asteroids, which come close to the Earth, could reveal vast new sources of raw materials. A manned mission to Mars could re-ignite our spirit of adventure and exploration.

Then there are the programs that "merely" appeal to our very human need to learn more about the universe we live in: the Space Telescope; a flyby of Halley's Comet and comet Tempel II; a lunar polar orbiter; the Venus radar probe; a Mars rover; the Galileo Jupiter probes; the planetary Grand Tour; the search for extraterrestrial intelligence (SETI).

The notorious Senator William Proxmire called NASA's SETI proposal a waste of money and gave it a Golden Fleece Award and suggested it be postponed "for a few million light-years (*sic*)." The SETI project was killed. Funding for a planetary Grand Tour was eliminated, and that once-in-a-lifetime opportunity slipped by. The Office of



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Management and Budget has effectively put the brakes on a Halley's/Tempel II flyby; the Space Telescope was almost canceled; Galileo was postponed by NASA's disastrous problems with the Space Shuttle (caused by perennial Congressional underfunding); the lunar polar orbiter and the Mars rover are just dreams now.

Now it looks like there will be no major planetary science programs from 1982 to 1985. Scientists and engineers aren't going to sit in their offices and wait. They're going to find other jobs. The space program will suffer another major brain-drain.

It needn't happen. The money's there. The Department of Defense and HEW each spend more in a week than NASA does in a year. And space exploration produces a lot for the money spent. It's labor-intensive. Not only would thousands of well-trained scientists and engineers have jobs, but the fallout, disparagingly called "spinoff," produces untold numbers of jobs in other areas. Astronauts and mission scientists are just the tip of the iceberg. Work will become available in the computer, electronics, and construction industries, not to mention aerospace.

We have only ourselves to blame for the death of the Space Age. In the end, it's a political problem. We elect the senators and congressmen more interested in "job security" than in adventure and imagination. We elected a President who mouths support of space exploration and picks a science advisor who opposes it for cost-benefit reasons. We elected a Vice-President with a clear senatorial record of opposition to the space program. And they are the people who appoint the NASA administrators more interested in churning out press releases about the Space Shuttle than in making sure they get enough money to do the job right the first time.

We must find leaders who believe in adventure, exploration, and imagination, and we must get them elected. Right now, there's no one who fits the bill — not even California Governor Jerry Brown. Today he calls for the exploration of the universe; six years ago he proclaimed the arrival of "the Age of Limitations." What will he proclaim next year? The Age of Linda Ronstadt?

If we want to revive the Space Age, we had better learn how to do it: with good PR and by practicing canny politics. The Cosmic Isolationists have no monopoly on those skills. We had better start learning from the enemy and counterattack.

Joel Davis
Seattle, WA

Notes on a Messier Marathon

For quite a few years I wondered if it would be possible to observe all of the Messier objects in one night. Maybe, I thought, just maybe, by observing from dusk to dawn, it could be done.

I now know that from the midnorthern latitudes it isn't possible. However, you can observe as many as 108 of the 110 Messier objects in one night. I know, because I've done it.

In August 1978 I began serious work on the Messier Marathon project. Surprisingly, one of the first things I needed to establish was the extent of the Messier catalog. It's actually four catalogs, published some 200 years ago, containing 103 galaxies, clusters, nebulae, star associations, and a few errors. Most of the errors, usually in the positions, have been corrected over the years — although not to everyone's satisfaction. Some seven more objects have since been added — objects apparently observed by Messier but not recorded as separate numbered objects. This gives a grand total of 110 Messier objects.

The next step was to determine the best time of year for a Marathon — the time when the greatest number could be observed. Using the planisphere and knowing the twilight times from my comet-hunting program, I found the best time is mid-March through early April. At this time, the Sun is hiding (or "overshadowing") the least number. Knowing this, I examined which objects would be difficult or impossible to observe on a day-by-day basis. This is what I found:

Before March 12, M-2, M-72, M-73, and M-30 all rise in the morning at twilight and are therefore difficult or impossible to see from midnorthern latitudes.

Between March 12 and 19, all the Messier objects are observable except M-30.

Between March 20 and 29, both M-74 and M-30 are difficult or impossible.

Between March 30 and April 3, only M-74 is hidden.

After April 3, M-74, M-77, and M-33 all become difficult.

Therefore, during two periods (March 12-19 and March 30-April 3) 109 of the 110 Messier objects can be observed in one night. This is under good conditions — dark skies, low horizons, and no Moon in the sky.

Next, I spent a number of hours constructing the observing order. There's a definite strategy. In trying to see nearly all the Messier objects on one night, you wouldn't want to be observing one object overhead while another you hadn't observed yet set. Nor would you want to see morning twilight approaching while objects up for several hours remained unobserved.

I'm sure there is no one best observing order for all types of observing sites. Local light pollution levels or high horizons in some part of the sky would certainly dictate a few changes in the observing order. However, the list I've evolved has been tested, and it works very well.

In the September 1978 issue of the *San Jose Astronomical Association Newsletter*, I suggested the Messier Marathon. The idea seemed to spark the imagination of many amateur astronomers. Pretty soon, the Astronomical Association of Northern California (AANC) had endorsed it and the San Jose group offered to sponsor it. We planned the Marathon for Friday and Saturday nights on two consecutive weekends, March 23-24 and March 30-April 1. The site was my comet-hunting site, Loma Prieta, a mountain 40 minutes south of San Jose. At the 3300-foot level, the skies would be fairly dark and the horizons low.

Of the four nights we observed, 3½ were clear. About 50 people were on the mountain, a dozen involved in the Marathon. On March 23-24, I found 107 of the 110 Messier objects using my 10" f/3.8 reflector. I missed M-74, which set before the sky was completely dark; M-30, which rose after morning twilight; and M-110, which was too low over the city lights in the evening and did not rise high enough in the morning.

Jack Zeiders, another member of the San Jose group, found 101 objects. Using a 10" f/5 reflector, Jack missed M-74, M-77, M-33, M-110, M-76, M-14, M-72, M-73, and M-30.

The next night, March 24-25, we had about 30 people on the mountain and lots of telescopes — including two 14" reflectors. Many of the observers spent the night searching for Messier objects.

The second weekend, on the night of March 30-31, Gerry Rattley, president of the San Jose group, and

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I each found 108 M-objects. Gerry, using a 10" f/5.7 reflector, missed only M-33 and M-74. I missed M-77 and M-74. A tree blocked Gerry's view of M-33, and the horizon got in my way for M-77.

Everybody had a good time. Some observers participated in the Marathon. Others worked on finding the 107 Messier objects required to join the AANC's Messier Club — a plaque goes to those finding all 107 (excluding M-40, M-91, and M-110), and a certificate is presented to those who find 75. But all 110 can be found in under two weeks if you know where to look — I found them all in the 12 days between March 19 and March 30.

Messier Marathon Notes

Now let's get down to brass tacks. Here's how to run your own Messier Marathon. First, let's clear up a few of those dubious Messier objects I mentioned before:

- *M-24* This is taken to be the 11th magnitude open cluster NGC-6603. It is 4 minutes of arc across, nestled near the northeast corner of a bright patch of the Milky Way itself 1½° across.
- *M-40* Messier seems to have seen the double star Winnecke 4, at 12^h 20^m, +58°22'. The stars are magnitudes 9.0 and 9.3 and 49 seconds of arc across. The galaxy NGC-4290, magnitude 13, is about 20' west.
- *M-47* This is the open cluster NGC-2422.
- *M-48* This is the open cluster NGC-2548.
- *M-73* This is a little group of four 10th magnitude stars. It is located at $20^h56.4^m$, -12°50'.
- *M-91* Messier may have seen a passing comet because there is nothing located in the position Messier gives. However, the 10th magnitude galaxy NGC-4548 is close by, and is usually taken to be M-91.
- *M-102* Some authorities believe this object is a duplicate observation of M-101. The galaxy NGC-5866, however, is very close to the position given by Messier, and it is therefore assumed to be M-102.
- *M-110* This is M-31's companion galaxy NGC-205. Messier drew it on a map of M-31 and so must have known about it.

Search Sequence

The search sequence tells you where to start observing, in the order most helpful to an observer. They're in 16 groups, each group representing one chart of the Skalnate Pleso *Atlas of the Heavens* by Antonin Becvar. Section 2, for example, is shown on chart II of the Atlas. Generally, they're listed in order of setting or rising — with a few exceptions to ease searching. You'll find yourself happily hopping from object to object, in curves, lines, and loops.

Messier Timetable

At last, here's the master program. To see the maximum number of Messier objects, you've got to catch some sections before they set and others as soon as they rise. The timetable shows the rising and/or setting times of the last object in the group to rise or the first object in the group to set in local time on April 1.

Stay on schedule — if you fall behind you'll see your Messier Marathon setting slowly in the West! This year, 1980, we'll have a new moon on February 16 and March 16, and Saturday falls on March 15, so perhaps the best times would be March 14-15 and 15-16, weather permitting. Under good conditions, it will be possible to observe 109 of the 110 Messier objects.

In 1981, conditions will not be so good. The Moon is new on March 6 and April 4, with full moon on March 21. This leaves only early April open for all-night observation.

I would like to encourage others to participate in a Messier Marathon. Good hunting and the best to you!

Don Machholz
San Jose, CA

M-74 by Martin Germano

Section	Setting	Rising	Objects
1	7:40 p.m.	------	2
2	8:00 p.m.	------	7
3	9:05 p.m.	------	12
4	11:30 p.m.	------	3
5	1:20 a.m.	------	7
6	------	------	2
7	------	------	10
8	5:00 a.m.	8:40 p.m.	20
9	4:00 a.m.	8:30 p.m.	2
10	------	8:40 p.m.	3
11	------	11:50 p.m.	5
12	------	1:50 p.m.	6
13	------	1:30 a.m.	15
14	------	2:50 a.m.	6
15	------	3:00 a.m.	5
16	------	4:20 a.m.	5

Messier Marathon Search Sequence

Section 1
chart VI
1) M-77
2) M-74

Section 2
chart II
3) M-33
4) M-31
5) M-32
6) M-110
7) M-76
8) M-34
9) M-45

Section 3
chart VII
10) M-79
11) M-42
12) M-43
13) M-78
14) M-41
15) M-93
16) M-47
17) M-46
18) M-50
19) M-48
20) M-1
21) M-35

Section 4
chart II
22) M-38
23) M-36
24) M-37

Section 5
chart VIII
25) M-44
26) M-67
27) M-65
28) M-66
29) M-95
30) M-96
31) M-105

Section 6
chart I
32) M-81
33) M-82

Section 7
chart IV
34) M-97
35) M-108
36) M-109
37) M-40
38) M-106
39) M-94
40) M-63
41) M-51
42) M-101
43) M-102

Section 8
chart IX
44) M-98
45) M-99
46) M-100
47) M-85
48) M-84
49) M-86
50) M-87
51) M-89
52) M-90
53) M-88
54) M-91
55) M-58
56) M-59
57) M-60
58) M-49
59) M-61
60) M-104
61) M-64
62) M-53
63) M-5

Section 9
chart XIV
64) M-68
65) M-83

Section 10
chart IV
66) M-3
67) M-13
68) M-92

Section 11
chart X
69) M-9
70) M-107
71) M-12
72) M-10
73) M-14

Section 12
chart XIV
74) M-4
75) M-80
76) M-19
77) M-62
78) M-6
79) M-7

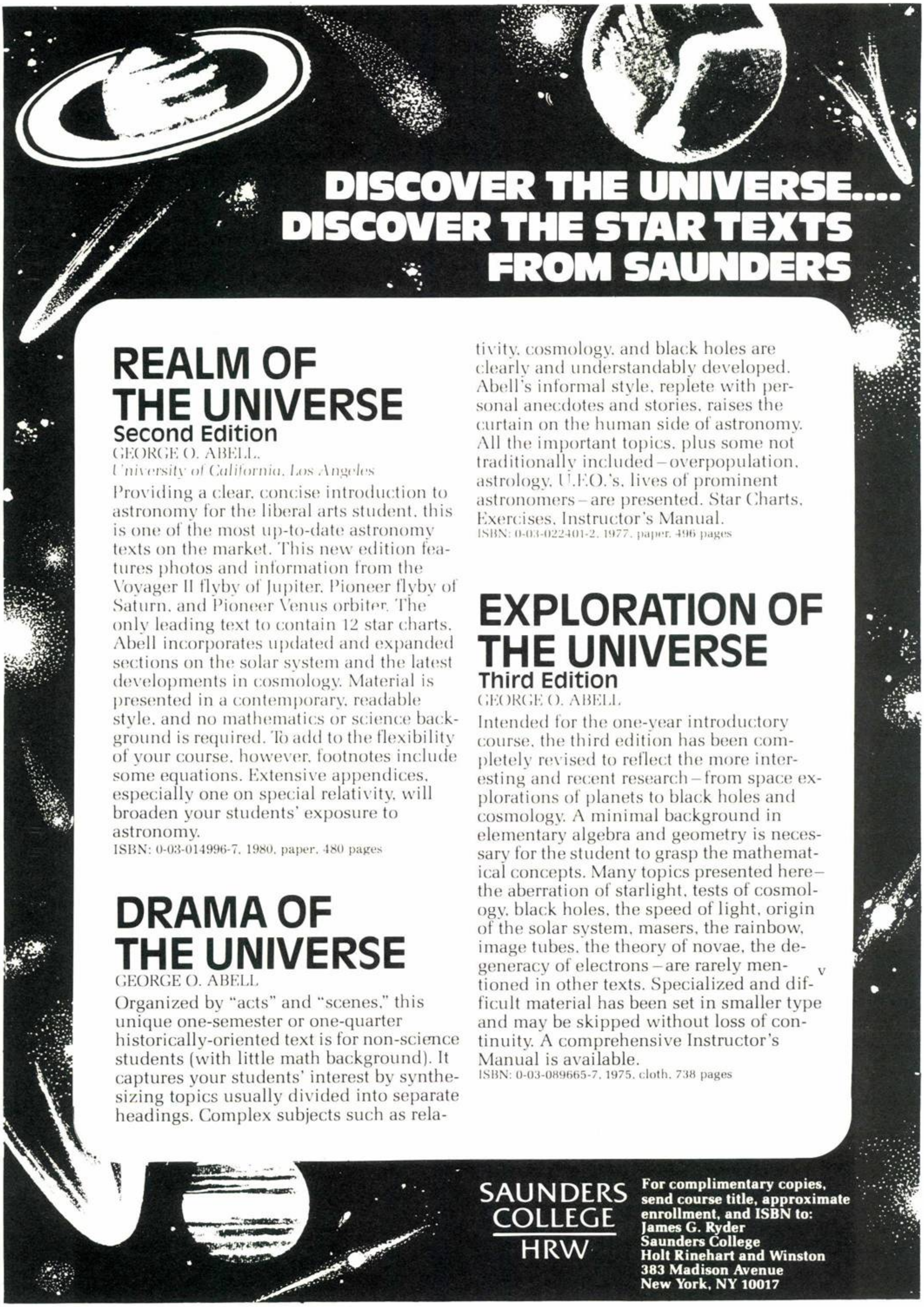
Section 13
chart X
80) M-27
81) M-71
82) M-11
83) M-26
84) M-16
85) M-17
86) M-18
87) M-24
88) M-25
89) M-23
90) M-21
91) M-20
92) M-8
93) M-28
94) M-22

Section 14
chart V
95) M-57
96) M-56
97) M-29
98) M-39
99) M-52
100) M-103

Section 15
chart XV
101) M-69
102) M-70
103) M-54
104) M-55
105) M-75

Section 16
chart XI
106) M-15
107) M-2
108) M-72
109) M-73
110) M-30

"Rising Repeats"
chart VI
(4) M-31
(5) M-32
(6) M-110
(7) M-76
(3) M-33



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sky almanac

the opposition of saturn

With the opposition of Saturn this month, you'll find all of the naked-eye planets (except Mercury) in the evening sky. At sunset, Orion lies on the southern meridian while Pegasus, Pisces, and Cetus slip from view in the west. Spring's constellations are rising in the east with Arcturus and the little circlet of Corona Borealis in sight by mid-evening.

april previews

2	Mercury at greatest elongation west
5	Venus at greatest elongation east
8	Last quarter moon
10	Pluto at opposition
15	New moon
	April fireball meteors
22	First quarter moon
	Lyrid meteors
24	Moon - Mars conjunction
	Moon - Regulus conjunction
	Moon - Jupiter conjunction
26	Moon - Saturn conjunction
29	Mars 1.8° north of Regulus
30	Full moon

The April Fireballs is an informal name given to a shower which produces bright meteors at irregular intervals between the middle of the month and the end. The region of sky they appear to come from is Aquarius-Capricornus.

The Lyrids are a once-numerous annual shower that seems to have dwindled in recent decades. Their time of maximum activity comes at about 9 p.m. EST on the 21st (2 hours UT on the 22nd, hence the date given above). The single-observer hourly rate will be around 15. Their radiant point lies on the Lyra-Hercules border near +34° declination.

Against the distant background stars gleam the brilliant, unwinking planets, their presence distorting familiar stellar configurations. You may have a hard job recognizing the outlines of Leo and Virgo thanks to Jupiter, Mars, and Saturn.

In the hour or two before sunrise, the "coming attractions" for summer appear. Vega rises before midnight, Antares around 1 a.m., and Deneb and Altair are up by 2 or 3. And last, you may catch a glimpse of the summer Milky Way before it fades from sight in the dawn.

Mercury

Mercury passes between the Earth and Sun on March 6th and will be close to the Sun's glare during the entire month. Since it becomes virtually invisible at these times, don't bother looking for it. The next good view of this planet will come in June, when it'll be relatively easy to see in the evening sky. (The upcoming morning appearance in April is poor.)

Venus

Very prominent high in the western sky as the Sun sets, Venus presents a truly dazzling sight. From night to night over the course of winter it has been moving steadily northward along the horizon, gaining altitude as it goes. By the end of March, it'll climb to its highest; starting in April its day-to-day path will move back down toward the horizon.

In a telescope, Venus' shape (which is about all you can discern) is slowly flattening to resemble a half moon. At the time of greatest elongation from the Sun (April 5), it'll be half-lit. During March, Venus' phase will shrink from 68% lit to 54%; its angular size will grow slightly from 17.2 seconds of arc to 22.3.

Earth

The vernal equinox, the time when the Sun crosses the celestial equator on its northward track, comes this year on the 20th, at 11:10 UT. On this day the Sun will rise due east and set due west, day and night each lasting 12 hours.

Moon

On March 1st, at full moon, there'll be a penumbral eclipse of the Moon. But as only the end of it will be visible from the extreme northeastern parts of North America, and since penumbral eclipses are nearly indetectable anyway, there won't be much to see.

On March 21st, those who live in the southeastern part of the U.S. will have a chance to see Aldebaran covered up by the Moon. This will be a daylight event. (Those living elsewhere in North America miss the occultation but get a conjunction.)

Daylight occultations are hard to observe, though by no means impossible. You need a very clear, unhazy sky and a red filter. Set up outside, locate the Moon, and search for Aldebaran to the east of the Moon. The time of disappearance is around 1:30 p.m. EST for those in southern Texas and Louisiana; farther to the east it comes a short while later. Good luck; you'll need it!

Mars and Jupiter

The second of the three conjunctions Mars makes with Jupiter during this opposition happens March 2nd. (Conjunctions are when two objects both have the same right ascension and are usually no more than a few degrees apart in declination.) In this case, Mars will pass a little more than 3° north of Jupiter.

Since both planets are past opposition, they will rise before sunset and as darkness falls, can be found high in the east.

Mars is now retrograding (moving

In the thick of the Milky Way you often find clusters of new stars surrounded by glowing gas. Seen here are two of these *stellar nurseries:* M-17 (top) in Sagittarius and M-16 in Scorpius. Photo by John Gleason.

Above is M-42, the famed Orion Nebula; at right, the region as a whole with bright Belt stars at the top and M-42 at the bottom. Photos by Ernest J. Coppola (above) and John Sanford (right).

west). In the coming weeks, you'll see it continue its westward path until early April, when it'll halt west of Regulus. Then resuming direct (eastward) motion again, it'll pass Jupiter for the third time May 4th. Easy and fun to watch, this particular series of events is quite rare. The last triple conjunction of Jupiter and Mars was in 1836-37.

Use a low power eyepiece on your telescope and you can easily hop back and forth between the two, comparing Jupiter's pale blaze with Mars' orange glow.

Earth's declination in the martian sky during March is about +20°, so we are looking down on Mars' northern hemisphere. (The Sun, too, has a northerly declination there; the martian summer solstice comes in early April.)

Mars' apparent size will decrease slightly during the month — from 13.8 arc-seconds to 11.8 — and its apparent brightness will drop from -1.0 to -0.3 magnitude. Mars has begun its retreat and observing conditions will continue to worsen until the next opposition "season" begins after its conjunction with the Sun 13 months from now.

Jupiter is likewise being diminished, though its great distance makes the effect far less. On the 1st its equatorial diameter is 44.7 seconds of arc and by the 31st this has shrunk only a bit — to 43.0. Its brightness changes hardly at all, dropping a tenth of a magnitude from -2.1 to -2.0.

Asteroids

1 Ceres is in the evening sky, setting around 9 p.m. local time. On the 15th, it's an 8.4 magnitude object at (1950 coordinates) $2^h 04^m 03^s$, +7°14'26".

2 Pallas is in conjunction with the Sun on the 10th, and is out of sight for now.

3 Juno sets around midnight, local time. Its (1950) coordinates on the 15th are: $7^h 10^m 01^s$, +11°21'37"; its brightness is 8.8.

4 Vesta is an evening object, setting about 11 p.m., local time. Its magnitude is 8.0, and its (1950) position on the 15th is $3^h 20^m 18^s$, +14°54'38".

Saturn

Being at opposition to the Sun on the 13th, Saturn remains visible the whole night through. Rising as the Sun sets, its path across the sky closely marks the anti-Sun direction. (It's not exact because Saturn is constantly moving and isn't precisely on the ecliptic anyway.)

Having spent the past few months in Virgo, Saturn's retrograde motion takes it westward back across the border into Leo, where it'll stay until July.

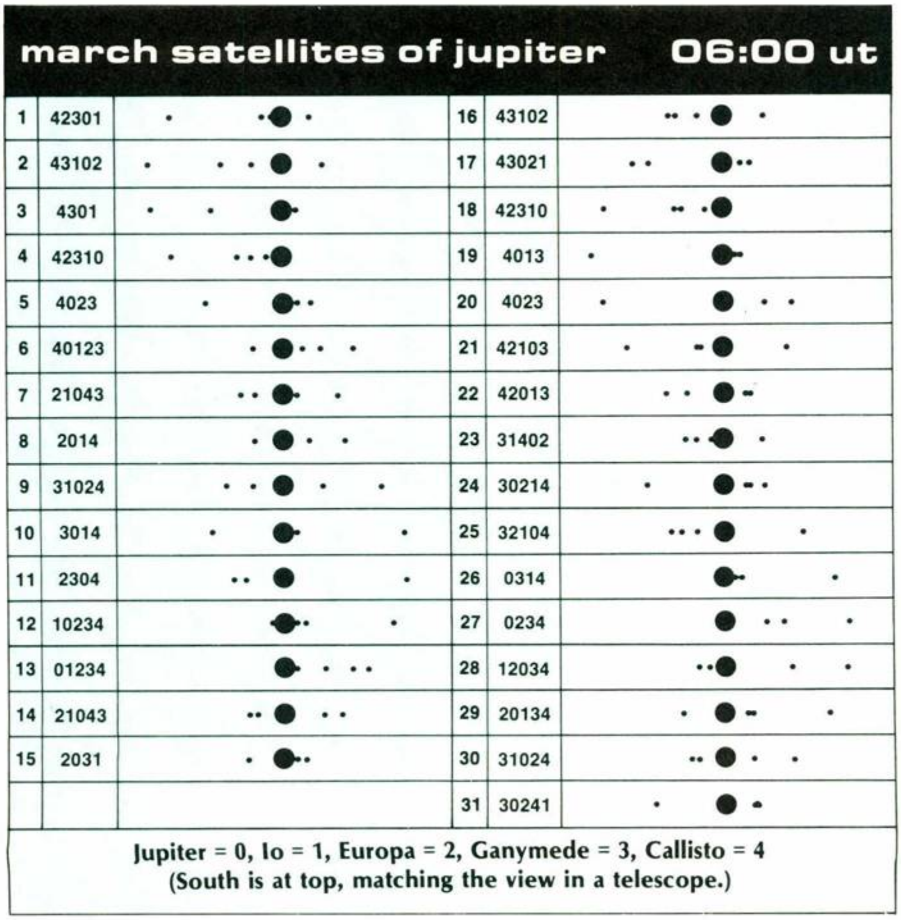
moon data

Last quarter: Apr. 8 at 12:06 UT in Sagittarius; new moon: Apr. 15 at 3:46 UT in Pisces; first quarter: Apr. 22 at 2:59 UT in Cancer; full moon: Apr. 30 at 7:35 UT in Libra. Perigee: Apr. 14 at 7^h UT; apogee: Apr. 26 at 20^h UT.

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times given in Sky Almanac are in UT unless noted otherwise. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 UT on Jan. 2, then the time in EST would be 10 p.m. Jan. 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m. on March 4.

Bordering Orion on the east lies the dim Milky Way constellation of Monoceros. Though its stars are faint, it has two magnificent clusters shrouded in nebulosity: the Rosette and the Cone. The Cone (shown here) is an assemblage of young stars and the dusty gas they are made from about 2600 light-years distant. The cone itself is an intrusion of opaque dust blotting some glowing gas from sight. Photo by Lee C. Coombs.



march satellites of jupiter 06:00 ut

1	42301	16	43102
2	43102	17	43021
3	4301	18	42310
4	42310	19	4013
5	4023	20	4023
6	40123	21	42103
7	21043	22	42013
8	2014	23	31402
9	31024	24	30214
10	3014	25	32104
11	2304	26	0314
12	10234	27	0234
13	01234	28	12034
14	21043	29	20134
15	2031	30	31024
		31	30241

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope.)

While giving the impression of closing in on the Jupiter-Mars group, Saturn won't in fact join them. Mars' rapid direct motion (once its retrograde loop has ended) will soon take it away eastward along the ecliptic from Jupiter, passing Saturn in late June. Jupiter won't meet Saturn until both are in the morning sky late this year.

Opposition shows Saturn off at its observable best. On the 15th, its equatorial diameter spreads 19.7 seconds of arc across; the polar dimension, 17.7 arc-seconds. The rings' full extent, if you could see it, would be 44.4 arc-seconds.

Devoted ring-watchers, who have been frustrated since last October, get a 10-day respite (from March 3rd to 13th) when they can try to snatch some observations of the rings.

Earth has been looking onto the north side of the rings since October 27th, while the Sun has remained on the south side. On March 3rd, the Sun crosses the ring-plane to join us on the north side, but ten days later on the 13th, we shift back to the south side where we'll stay until July 23rd.

During those 10 brief days comes your best opportunity to glimpse the rings' thin line. Start watching before the Sun crosses over from the south side and keep at it every clear night until the rings dim from view as Earth quits the northern side. Each night the sights will change slightly as the lighting conditions and your viewing angle alter day by day.

Uranus

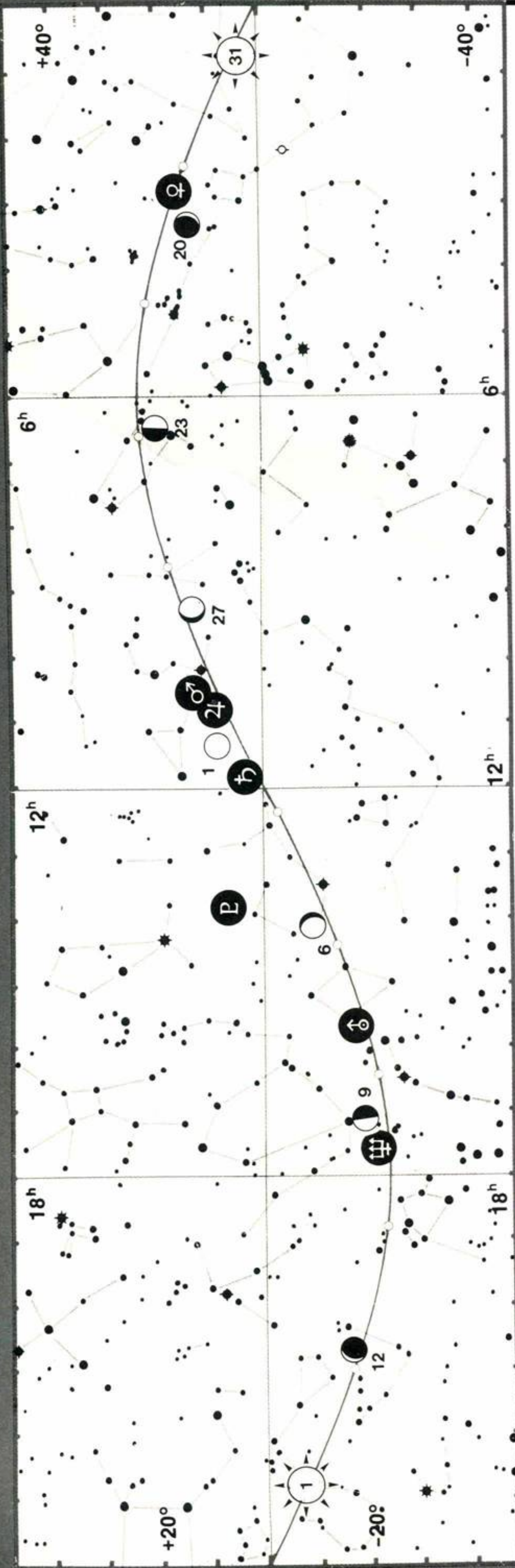
Uranus is in eastern Libra and so doesn't rise until about midnight local time (on the 1st) or 10 p.m. (by 31st). Two degrees directly south of magnitude 5.6 Zeta (ζ) Librae, you can find it best by scanning south of the star with a medium power eyepiece and switching to high power when you spy its 3.8″ disk.

Neptune

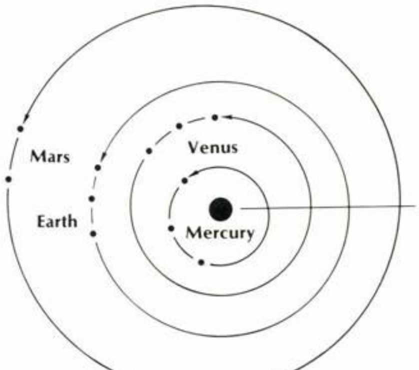
Neptune lies in southeastern Ophiuchus, a region that rises around 2 a.m. local time on the 1st and midnight on the 31st. The key to locating it is the magnitude 4.5 star Xi (ξ) Ophiuchi. Having found Xi, scan about ¾° south and about 2° east. Neptune will have a 2.4″ disk and will look similar to a star.

Planet Finder

March 1980

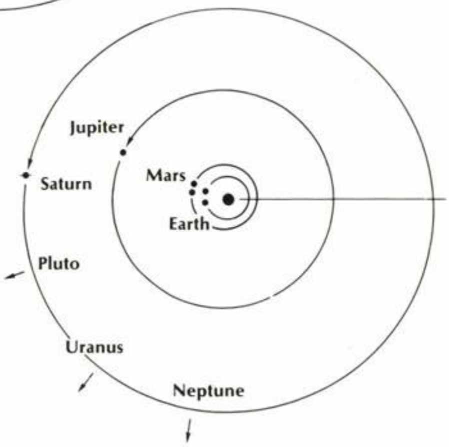

+40°
-40°
31
20
6h
6h
23
27
1
12h
12h
6
9
18h
18h
12
1
+20°
-20°

The Planets in Their Courses


Mars
Venus
Earth
Mercury

The positions of Mercury, Venus, Earth, and Mars in their orbits are shown for the beginning, middle, and end of the month. (Mars for the beginning and end only.) The vernal equinox is the line at right.

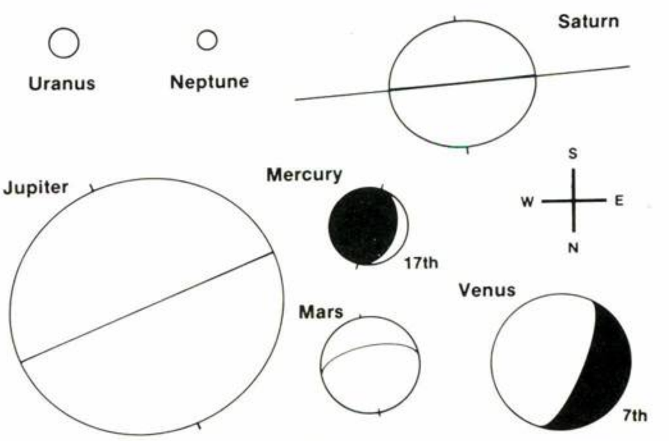
The orbits of Earth, Mars, Jupiter and Saturn are shown at right. Earth and Mars' positions are for the first and last of the month; Jupiter and Saturn for midmonth. The outermost planets' directions are indicated.


Jupiter
Saturn
Mars
Earth
Pluto
Uranus
Neptune

Positional Data

Planet		Date	R.A. (1980.3)	Dec.	Mag.	Distance (AU) from	
						Earth	Sun
Mercury	☿	10	$22^h48.9^m$	−4°03.6′	+2.4	0.62	0.39
		20	$22^h35.1^m$	−7°56.2′	+1.2	0.70	0.44
		30	$22^h55.3^m$	−8°07.9′	+0.7	0.83	0.46
Venus	♀	10	$2^h03.6^m$	14°00.9′	−3.8	0.91	0.72
		30	$3^h28.2^m$	21°49.4′	−3.9	0.76	0.72
Mars	♂	15	$10^h10.5^m$	15°29.3′	−0.8	0.71	1.66
Jupiter	♃	15	$10^h21.2^m$	11°40.9′	−2.0	4.46	5.40
Saturn	♄	15	$11^h40.2^m$	4°45.9′	+0.8	8.45	9.44
Uranus	⛢	15	$15^h32.8^m$	−18°51.1′	5.9	18.23	18.74
Neptune	♆	15	$17^h28.3^m$	−21°51.8′	7.7	30.23	30.28
Pluto	♇	15	$13^h42.8^m$	8°17.3′	13.8	29.32	30.16

Telescope View


Uranus
Neptune
Saturn
Jupiter
Mercury
17th
S
W
E
N
Venus
Mars
7th

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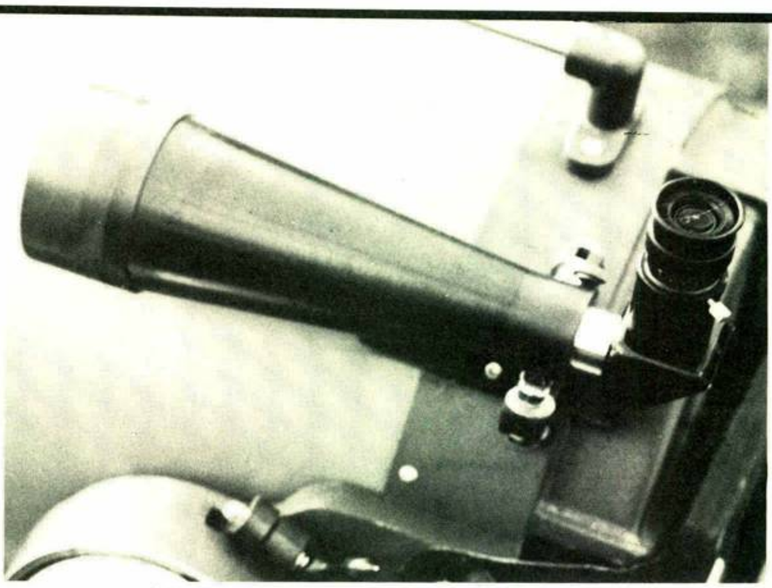

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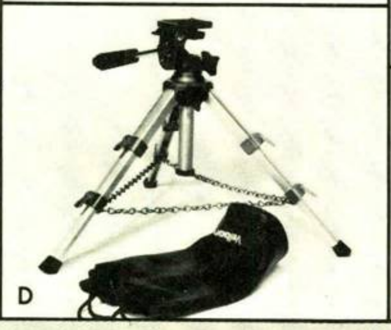
A

B

E

G

C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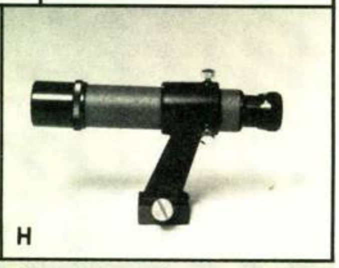
H

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photographing the sun

photography in astronomy

by
James Felbab

Would you like to have photos of one of the most active solar maximums in the last two hundred years? You can, and you can take them yourself. It's easy. Solar Cycle 21 is expected to peak about the same time this issue arrives, so dust off that telescope-to-camera converter and read on.

The Sun is a very interesting subject for indepth study at any time, but even more so when it is active. Unfortunately, too many observers take it for granted. Observing and photographing the Sun is not only fascinating, it's just plain enjoyable. Like snowflakes, no two sunspots are exactly alike, and not only are they all different, but each sunspot shows changes from one day to the next. The Sun is truly one of the most beautiful and intriguing objects in the heavens. Once you see our active star up close, you gain a new appreciation for all other stars, and your view of the night sky will never be the same.

Sunspots, Plages, and Flares

On any clear day during the maximum you are likely to see dozens of sunspots, some incredibly large. The larger spots are several times the diameter of the Earth and the largest groups can span 100,000 miles. Perhaps this maximum will surprise us with a sunspot group larger than "the colossal group of 1947," which covered two billion square miles.

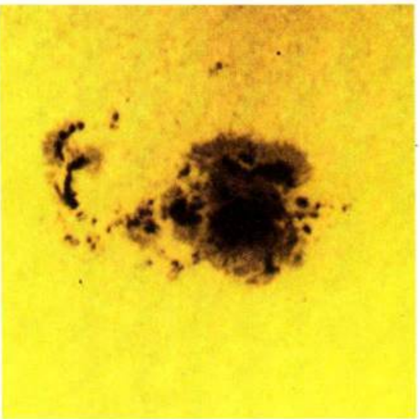
In appearance, sunspots consist of a very dark core called the *umbra* surrounded by a lighter area called the *penumbra*. Sunspots are pockets of gas that have been restrained by a strong magnetic field and cooled to about 3500° Kelvin. Since they are much cooler than the surrounding area (6000° K), they radiate less light.

Plages, sometimes called *faculae*, are whitish areas surrounding sunspots and other active regions in the photosphere (sphere of light). They are easier to spot near the Sun's limb.

Flares are massive eruptions which spew huge amounts of radiation and nuclear particles into space. They are responsible for aurorae and disruptions in communications. If you are very fortunate, you may witness a rare white light flare.

All these phenomena are visible with inexpensive amateur equipment and can be photographed easily, but before continuing, a note on safety is necessary:

Never look at the sun without adequate protection. Doing so may permanently damage your eyes without your being aware of it at the time.



Large sunspot groups, such as the one pictured above, should be relatively common during the current period of high solar activity. Photograph by Jean Dragesco.

And always remember to cover your finder and guidescope when observing the Sun. Failure to do so may result in painful burns.

Telescope

Almost any telescope is suitable for solar photography, except for the open-frame reflector. If you are using a Newtonian, you must cover the primary end of the tube so that no light enters. To capture the full solar disk on 35 mm film, you will need an effective focal length (EFL) less than 100" (2500 mm); focal lengths of about 80" are very effective. For close-ups of individual sunspot groups, use eyepiece projection for EFLs up to 1000".

Your telescope should be mounted on a solid tripod or pier and, for greatest convenience, be equipped with a clock drive. Be sure that you set it up on firm ground where no vibrations will be passed on to the telescope. Cover your finder and guidescope when you set up to avoid forgetting later.

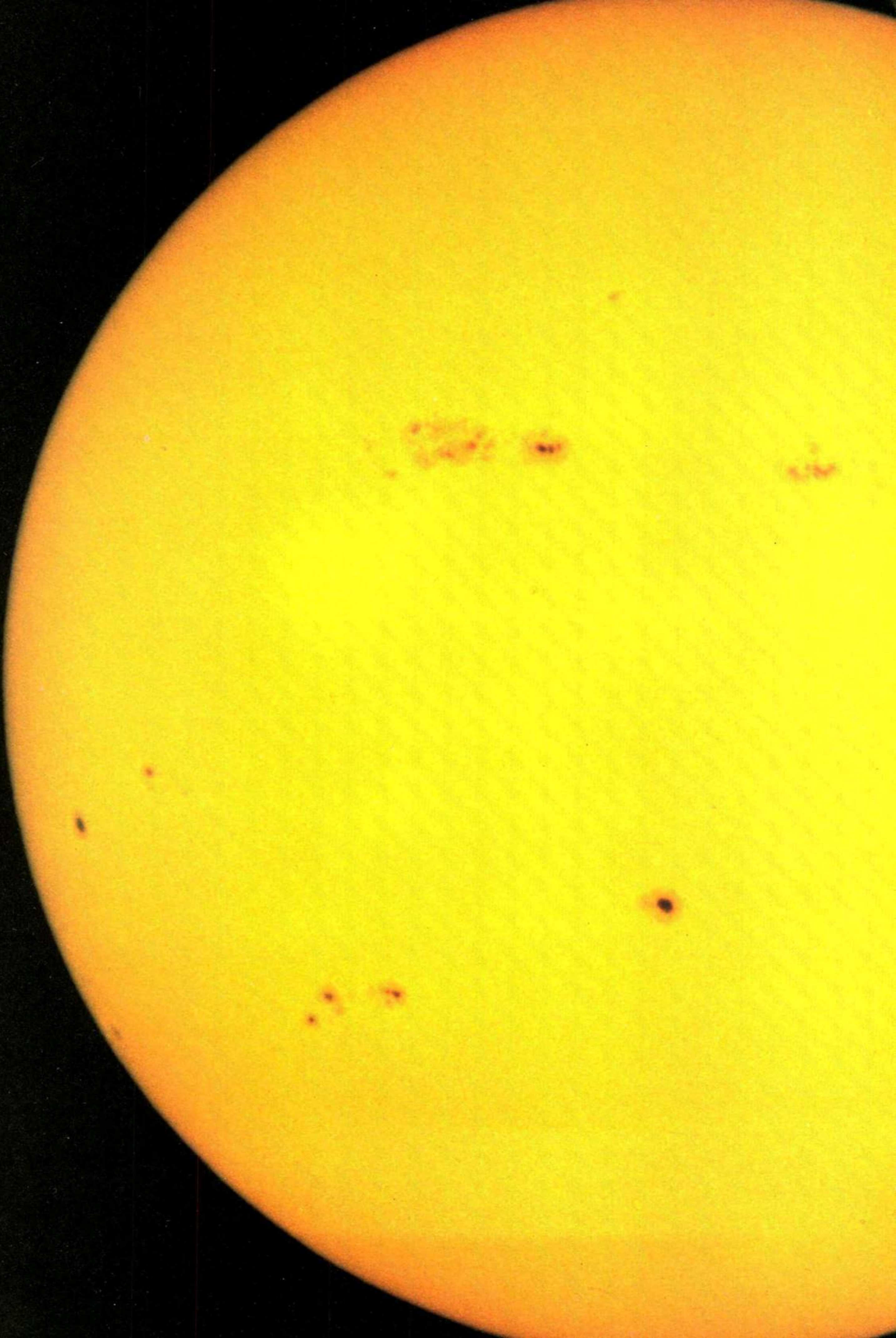
Cameras

While almost any SLR camera will work well, those having interchangeable focusing screens offer a big advantage. The standard focusing screens provided with SLR cameras are fine for 35 to 300 mm lenses, but they are much too coarse for focal lengths over 500 mm. With this screen, it is difficult to achieve that exact point of focus so critical for sharp pictures.

If your camera has the capability for changing this screen, you should do so. A clear field (aerial image) or a very fine matte screen is best. With one of these in place, you will notice a much brighter viewfinder image along with greatly improved focusing ability. (Because it's so important to achieve precise focus, I would also recommend the use of a *critical focusing magnifier*. Typically, these devices provide two to five times magnification of the image at the flip of a lever.)

Other Equipment Required

Besides a telescope and SLR camera, you will need a safe solar filter and a telescope-to-camera converter for solar photography. Some optional, but very handy, accessories include: a critical focusing magnifier, an air-type remote shutter release, and a



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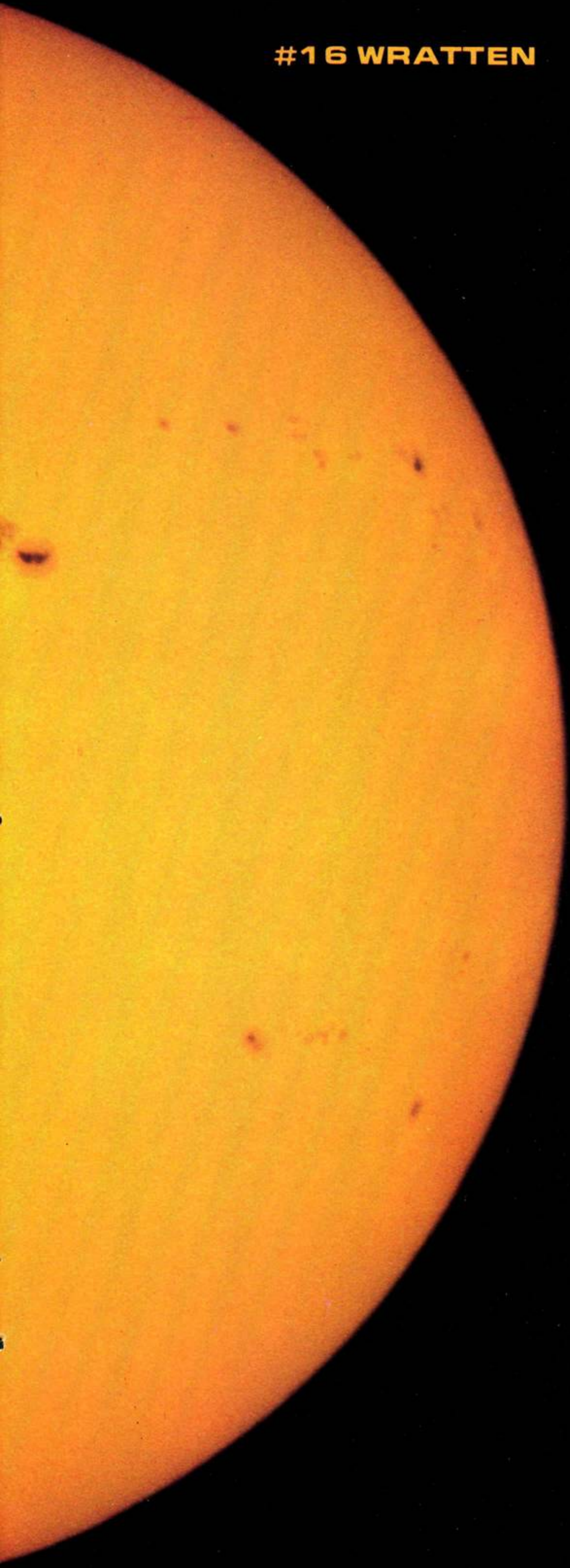

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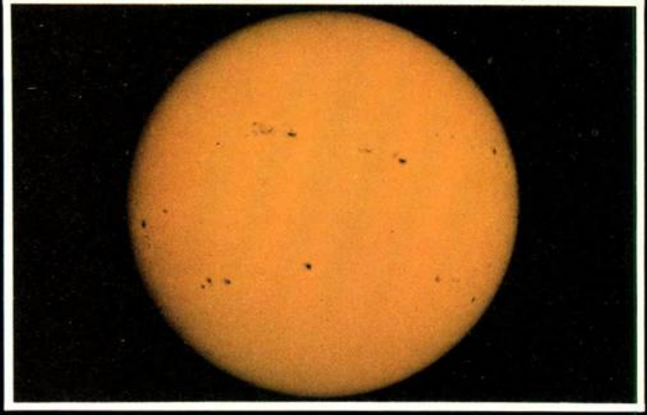
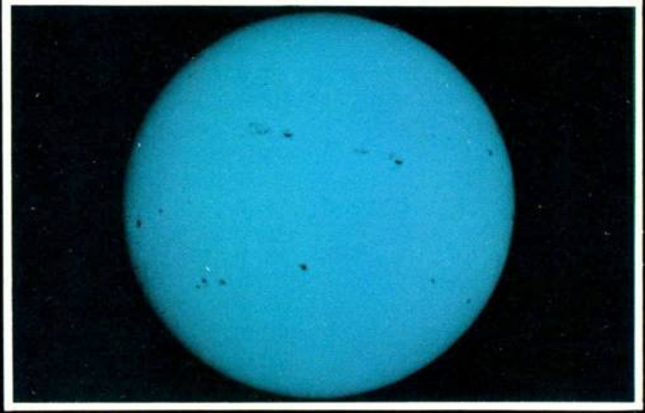


SOLAR SCREEN



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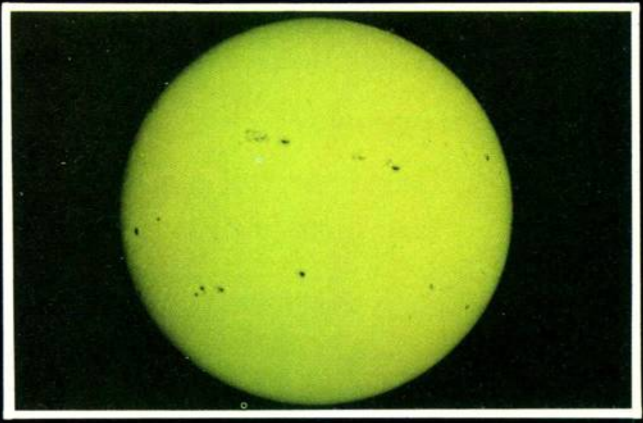


This photograph of the Sun, taken on November 10 of last year, shows a large number of sunspot groups both north and south of the solar equator. A color photograph of the Sun using only an objective filter (such as the Solar Skreen used on all the photographs seen here) results in an unnatural blue. The addition of various Wratten filters can render an image with a more acceptable color. Experimentation will determine which filter works best for your particular equipment. Photos by the author.

notebook to record exposure and related items. (A cassette recorder handles this task nicely.)

Of the various solar filters on the market, the full aperture metalized thin film or glass type is the best choice. They block 99.999% of the visible and infrared light from entering the telescope. This is the reason they work so well. Blocking the rays before they enter the telescope eliminates heat buildup and the resulting turbulence or convection in the tube that can ruin the image.

Welder's glass filters in threaded eyepiece mounts aren't safe nor do they prevent the heat buildup previously mentioned. Protect your eyesight: if you own one of these filters, throw it away.

(The solar filter I use is a full-aperture filter made of aluminized polyester. If treated properly, these filters will last for years. Another strong point in their favor is their very low cost. I can think of only one disadvantage of the aluminized polyester filter: it doesn't render the Sun in its correct color. Visually, the Sun appears a whitish color, very much as if you were viewing a black and white slide. Direct photographs appear a pale-to-medium blue, but I've found an additional #15 or #16 Wratten corrects for this nicely. There is currently advertised a nickle-coated thin film filter which claims to render the Sun in its familiar orange color. I haven't had the opportunity to use this filter, so I can't report on its performance.)

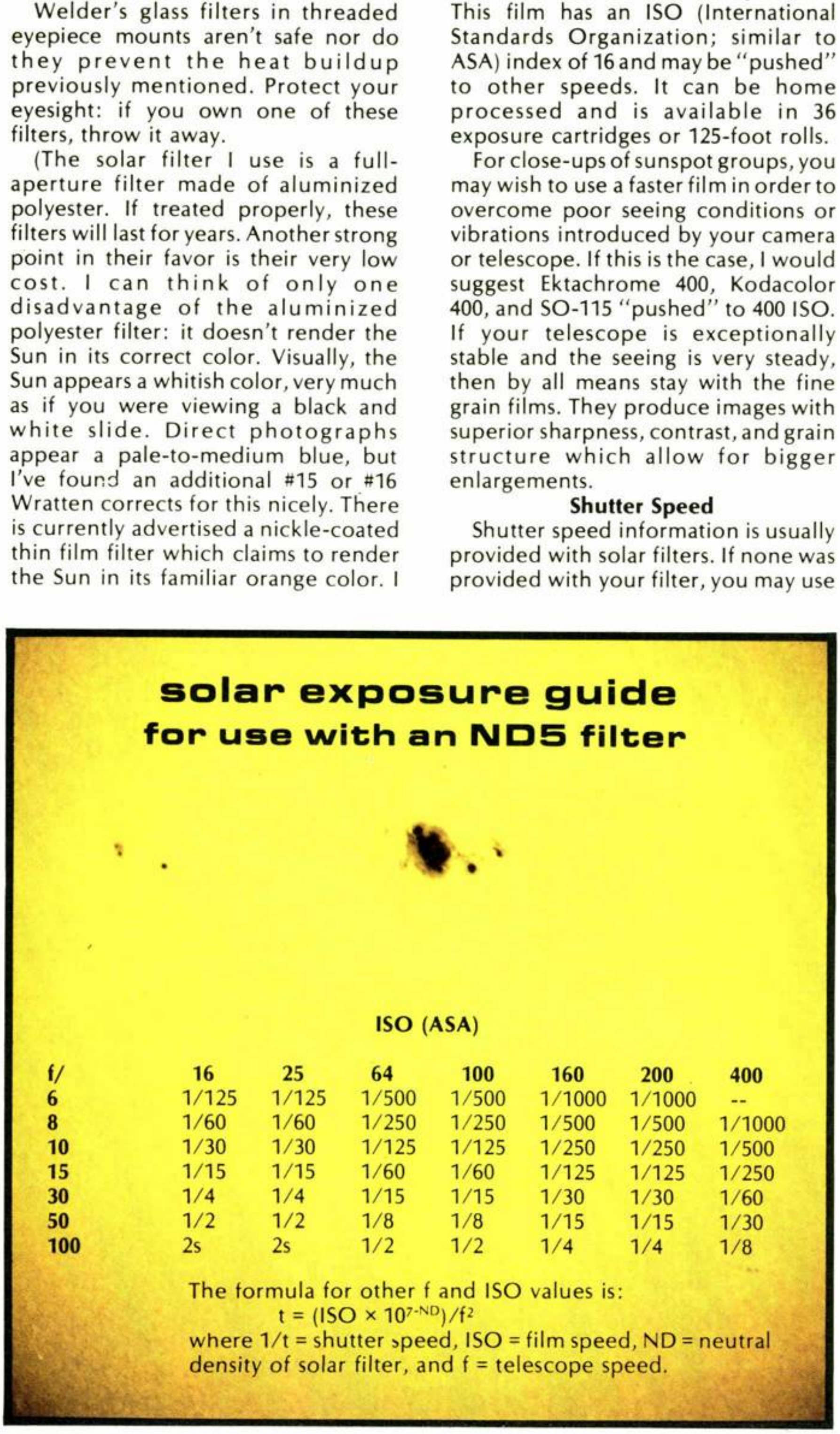
Film

Use fine grain film for photos of the full Sun. My personal choice for color slides is Kodachrome 25 or 64; for prints, Kodacolor 100 and fine-grain high contrast Kodak SO-115 (for black and white). An additional color slide film you may wish to try is PCF 2483. This is a photomicrography film of very high contrast, resolution, and color saturation which is almost grainless. This film has an ISO (International Standards Organization; similar to ASA) index of 16 and may be "pushed" to other speeds. It can be home processed and is available in 36 exposure cartridges or 125-foot rolls.

For close-ups of sunspot groups, you may wish to use a faster film in order to overcome poor seeing conditions or vibrations introduced by your camera or telescope. If this is the case, I would suggest Ektachrome 400, Kodacolor 400, and SO-115 "pushed" to 400 ISO. If your telescope is exceptionally stable and the seeing is very steady, then by all means stay with the fine grain films. They produce images with superior sharpness, contrast, and grain structure which allow for bigger enlargements.

Shutter Speed

Shutter speed information is usually provided with solar filters. If none was provided with your filter, you may use the table on this page for a starting point. Bracket your exposures ± 2 stops to determine the optimum exposure for your telescope and filter combination.



solar exposure guide
for use with an ND5 filter

f/	ISO (ASA)						
	16	**25**	**64**	**100**	**160**	**200**	**400**
6	1/125	1/125	1/500	1/500	1/1000	1/1000	--
8	1/60	1/60	1/250	1/250	1/500	1/500	1/1000
10	1/30	1/30	1/125	1/125	1/250	1/250	1/500
15	1/15	1/15	1/60	1/60	1/125	1/125	1/250
30	1/4	1/4	1/15	1/15	1/30	1/30	1/60
50	1/2	1/2	1/8	1/8	1/15	1/15	1/30
100	2s	2s	1/2	1/2	1/4	1/4	1/8

The formula for other f and ISO values is:

$$t = (\mathrm{ISO} \times 10^{7-\mathrm{ND}})/f^2$$

where 1/t = shutter speed, ISO = film speed, ND = neutral density of solar filter, and f = telescope speed.

Color Correction

If you decide to use a color corrector filter such as the #15 or #16 Wratten, the shutter speed must be slowed by about one stop. For example, if the table indicates the shutter speed to be 1/250 second, the proper shutter speed with the filter would be 1/125 second. Films other than the Kodachromes will require that you experiment with different color correction filters. Fuji R100 balances out well with a #8 or #9 Wratten filter, and PCF 2483 works well with a #12 or #15 Wratten. These Wratten filters come in small gelatin squares, are inexpensive, and can be obtained from your local camera store. They are easily cut with a scissors to suit your needs.

False Color

You can actually produce color slides from black and white film. The film is Panatomic X, developed into a positive. When used for positives, this film has an ISO of 80. This film is almost grainless and produces crisp black and white slides. Sandwich this slide with a deep yellow color gelatin, project it, and be ready for a surprise. The color is hard to fault. If the color gels are not available from your camera store, you might try ordering them from Spiratone, Inc., 135-06 Northern Blvd., Flushing, NY 11354.

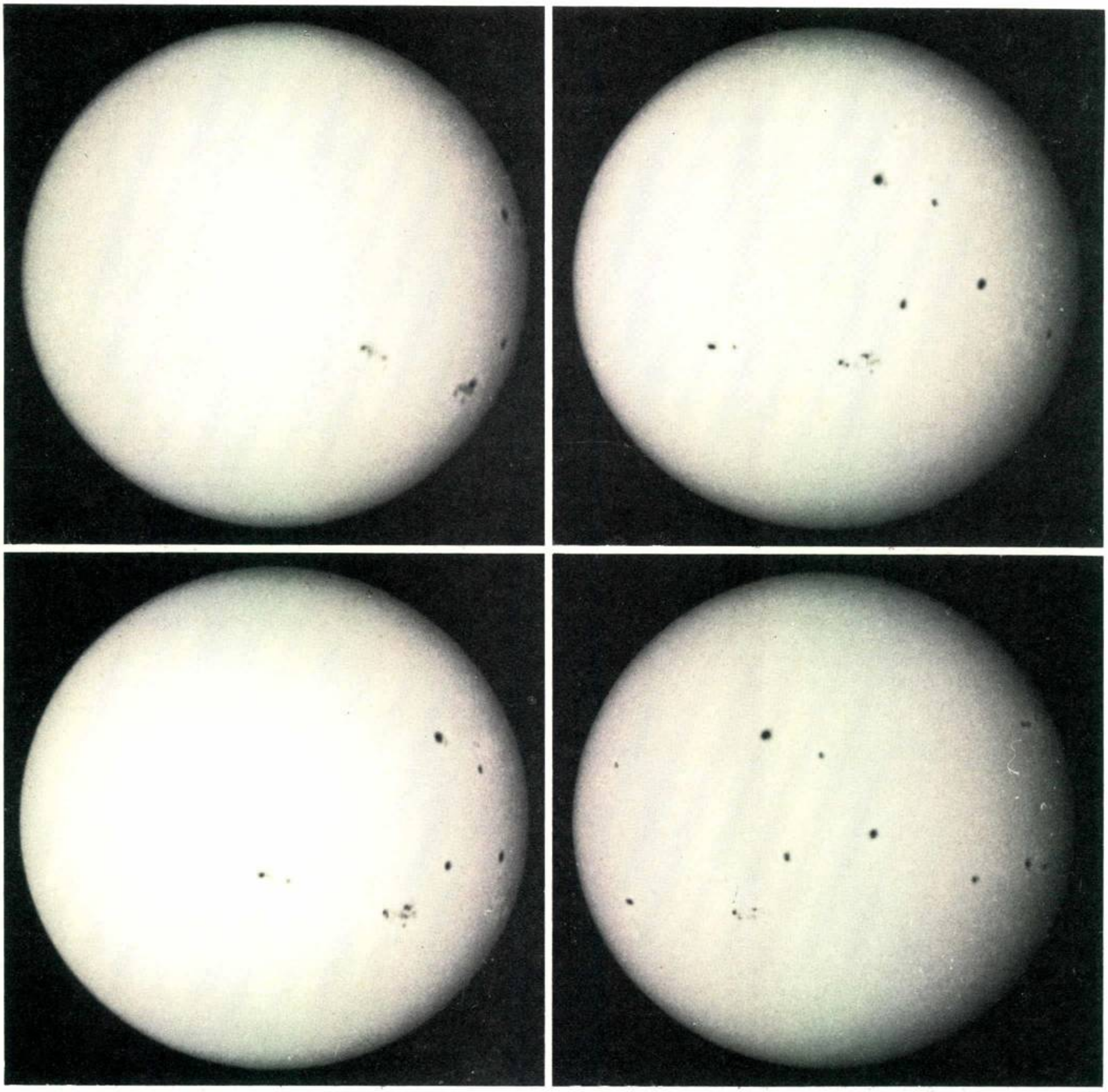
The Gremlins

There are three gremlins you must strive to control if you expect sharp solar photos. Fortunately, much can be done to keep them in check.

●*Imprecise Focus.* Take your time when focusing. If you're not sure that you have precisely focused, you probably haven't. Use a critical focusing magnifier. If your camera accepts other focusing screens, replace the conventional screen with a clear (aerial image) or fine matte screen.

●*Poor Seeing.* You may think that there's nothing you can do to control poor seeing. This isn't true — poor seeing is caused by turbulence, and frequently the most turbulent air is right inside your telescope tube. Some telescopes may require up to an hour to reach thermal equilibrium depending on the temperature differences, so set up your telescope well ahead of time. (See "Cool Your Telescope," ASTRONOMY, February 1980.)

Another method of controlling turbulence is to take your solar photos in midmorning when the Sun is high but before its heating effects cause the atmosphere to waver. Wait for the quiet moments, then shoot.



The presence of sunspots makes it easy to take a series of photographs illustrating the Sun's rotation. The photos above were taken on alternate days from June 1 to June 7, 1979 by Lance Allred.

●*Vibration*. The third gremlin, vibration, is the most difficult to control but it's not impossible. If your camera has a mirror lockup feature, use it. Wait a few seconds to let things quiet down and then trip the shutter. Use an air-type remote shutter release. This will provide an added measure of isolation between you and your camera. A bag of split-shot or a bean bag pillow placed over the telescope may help damp out vibrations. Set up your telescope on solid ground out of the wind. Sometimes you can use a building as a wind shield. If you are unable to get out of the wind, try to wait for the still periods. Have a friend walk heavily around your telescope while you are viewing through it. Was the image steady? Beef-up your tripod or add weight to the base and repeat this process until no more improvement can be noticed.

Moment of Truth

After your slides or prints have been processed, examine them critically. Evaluate them for correct exposure. Consult the notes you made for shutter speed and other related data. Is the color correct? If the #16 Wratten resulted in an image too orange, try the weaker #15 or #12 Wratten. If not orange enough, a #21 may work better. Check your slides or prints for sharpness. A loupe of about 8 power is helpful for this examination. Have the gremlins been kept in check?

Another important job to do as soon as each batch of slides comes back is to *label them* — at least the date and time of exposure should go on *each* and *every* film. Six months later, you'll never figure out what's what if you haven't labeled them.

If you feel you have a particularly good slide or print, you may wish to make an enlargement. Prints of the 8 x 10 or 11 x 14 size are breathtaking. With only a little experience and experimentation, you'll find you are producing strikingly beautiful photographs of the Sun. And before long, you will have your own gallery of solar portraits.

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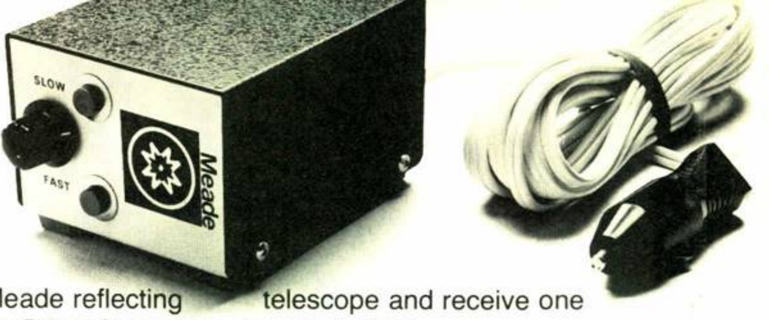

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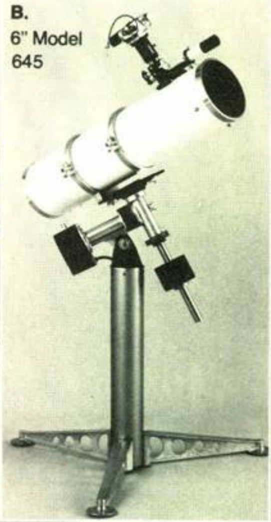
A. 6" Model 591


B. 6" Model 645

C. 8" Model 826

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D. 10" Model 1060

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A. MODEL 591: 6" f/8 with Motor Drive	**$319.50**
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F. MODEL 1266: 12½" f/6 with Motor Drive	**1675.00**

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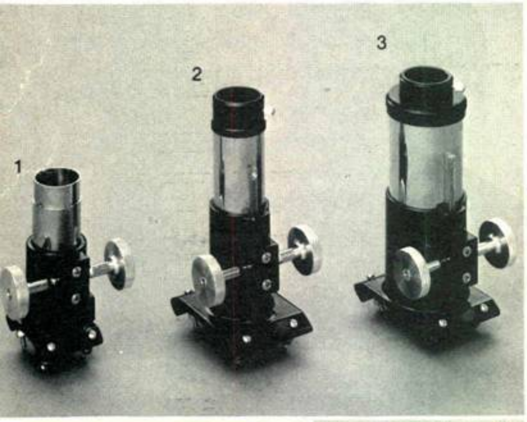

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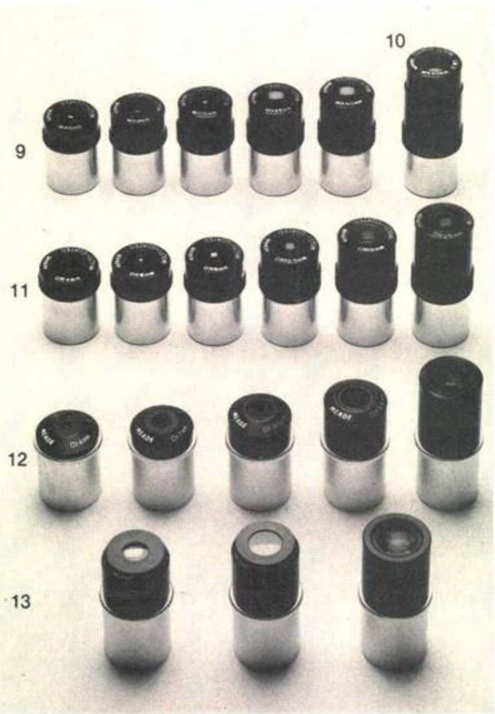

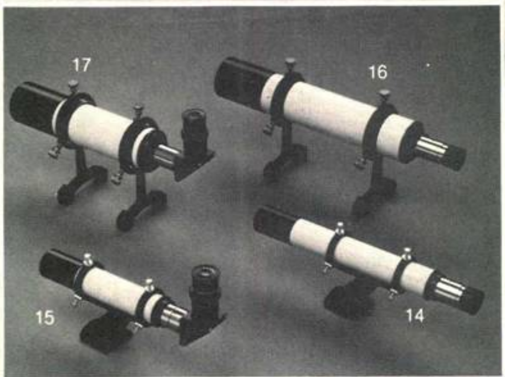

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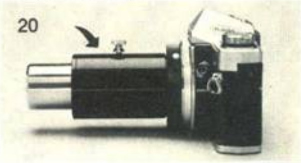

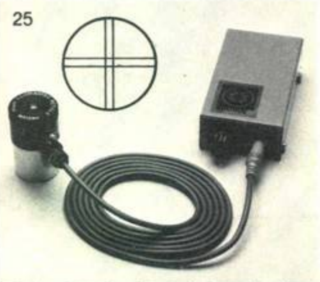

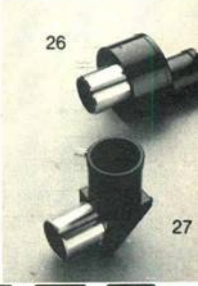

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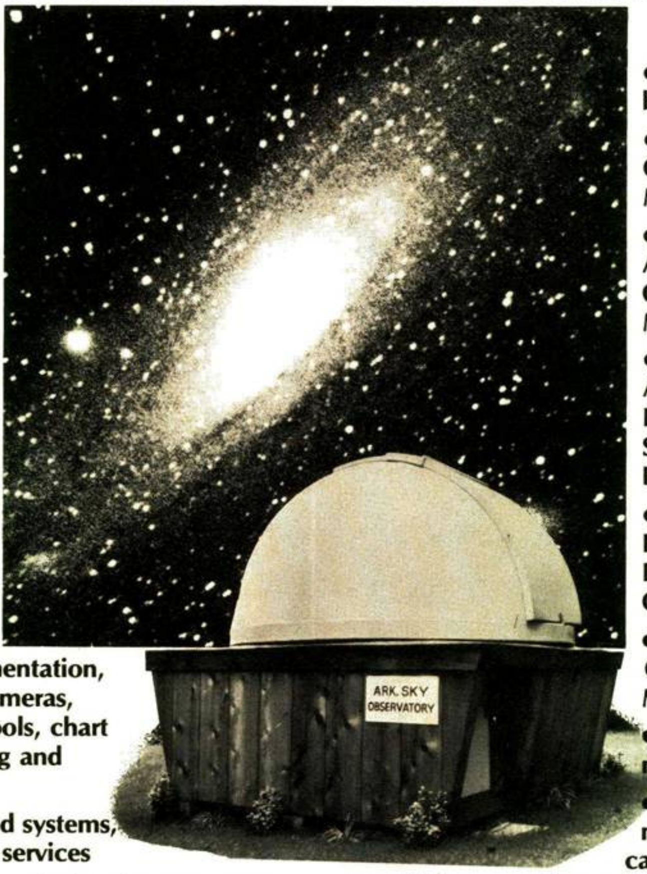

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building a sundial

equipment atlas

The humble sundial is probably the oldest scientific instrument in existence. While its usefulness to science ended long ago, many people still build them, perhaps because they're such a nice, elegant demonstration of celestial order.

Esthetics, too, play a large part in their appeal, since accuracy isn't often thought to be a distinguishing feature. As Hilaire Belloc once wrote: "I am a sundial, and I make a botch / Of what is done far better by a watch," and few would disagree if they've ever compared clock time with "sun-time" read from the face of a dial like those commonly sold in garden stores. But sundials aren't always dismally inacccurate: after all, the French railway system used precisely-made dials for accurate local time throughout their network as late as 1901.

Bringing up the matter of accuracy at the outset may sound apologetic, but it's necessary if only to forestall those tiresome killjoys who delight in scoffing at any timepiece that isn't some state-of-the-art marvel, humming with shuttling cesium atoms, or the latest fad in masers.

With sundials, accurate is as accurate does. You, like some people, might even end up relishing the discrepancies. Maybe you'll find yourself feeling that watch time is too artificial and dial time more "natural."

In any case, they're fun to make, so here are directions for constructing a few. The descriptions are roughly in ascending order of difficulty, so jump in where you like. (And as a special treat for the fussy, there's even a box on how to make them into very accurate timepieces.)

Sundials come in all sizes and shapes, and have been made from virtually every material imaginable. At their simplest, anything which casts a shadow onto a surface can in principle be made into a dial, though in practice you'd be crazy to use any old bent stick and an uneven surface.

The Horizontal Dial

For simplicity's sake, let's begin with a common horizontal dial, whose lookalike cousins used to turn up nearly everywhere, often on a pedestal in a garden defended by a bloodthirsty rosebush.

This type of dial has a flat horizontal plate in the middle of which is an upright triangular blade. Scribed or painted on the plate are the hour divisions. The blade is called the gnomon (NO-mun). The tip points to the celestial pole. The edge of the gnomon casts a moving shadow on the dial, marking the time as the Earth's rotation moves the Sun across the sky.

In building any dial, the chief difficulties are laying out the lines accurately, making and placing the gnomon correctly, and stably mounting the whole thing outside in the correct orientation.

Laying out the lines can be done by either of two methods. One is lengthy and time-hallowed, the other modern and easy. The old way, using geometrical constructions, can be a lot of fun if you like fooling around with a compass and straightedge. The new way uses the trig functions found on many simple pocket calculators, and this is what we'll show here. (Using the quick and dirty method isn't mere laziness; if we explained fully the geometrical method for making this one type of dial, it would take over the rest of the article, leaving no room for any other design.)

Since the Earth rotates once (360°) in 24 hours, during each hour the Sun moves 15° across the sky. To figure out where the hour lines should be for your dial, take a sheet of paper and draw up a little table. In the first column, list the hours between 6 a.m. and 6 p.m. The next column (which we'll explain in a minute) contains the hour angle of the Sun; the last column lists the angle each hour line makes with the noon line.

The Sun's hour angle at noon is 0° (by definition), that is, when it lies on the meridian, being neither east nor west of it. At 11 a.m. and 1 p.m., its hour angle is 15°, at 10 a.m. and 2 p.m. the hour angle is 30°, and so it goes down to 6 a.m. and 6 p.m., where the solar hour angle is 90°. In the second column of your table insert the hour angles for each of the hours. If you want to lay out half and quarter hours, the increments are 7½° and 3¾°.

Now for the magic of numbers! You work out the angle between the noon line and any particular hour line by using the following formula:

$$A = \text{arc tan } [(\sin L) \times (\tan H)]$$

where A is the angle you want,
L is the dial's latitude,
H is the Sun's hour angle, and
arc is the inverse of the trig function named.

You'll need a set of trig tables or a calculator having trig functions to work out the angles. Since the hours are symmetrical on either side of noon, you need calculate only one set, from 6 a.m. to noon, say, and then lay the lines out in reverse order on the other side of the noon line.

To save grief, make a full-size cardboard model in pencil before you start in on the real thing. Assemble a protractor, a straightedge, and the appropriate tools for working the material your dial's to be made from (wood, metal, stone, etc.).

The gnomon is attached to the dial plate exactly on the noon line. Its upper edge makes an angle with the dial plate *equal to your latitude*. The material it's made from isn't terribly important so long as it's weatherproof and stiff enough not to bend easily.

If the gnomon is more than about an eighth of an inch thick, watch out — because then the edge casting the shadow isn't directly over the noon

we know all the angles...

No calculator? Hate math anyway? In this table you'll find the angles for your horizontal dial. Look up your latitude (round off to the nearest degree) and the angles are given in degrees for each hour and half-hour. The noon line is the "zero point" and the 6 a.m. - 6 p.m. line lies at 90° to it in every latitude.

latitude	5:30 6:30	5:00 7:00	4:30 7:30	4:00 8:00	3:30 8:30	3:00 9:00	2:30 9:30	2:00 10:00	1:30 10:30	1:00 11:00	12:30 11:30
20°	68.9°	51.9°	39.5°	30.6°	24.0°	18.9°	14.7°	11.2°	8.1°	5.2°	2.6°
25°	72.7	57.6	45.6	36.2	28.8	22.9	18.0	13.7	9.9	6.5	3.2
30°	75.2°	61.8°	50.4°	40.9°	33.1°	26.6°	21.0°	16.1°	11.7°	7.6°	3.8°
31°	75.7	62.5	51.2	41.7	33.9	27.3	21.6	16.6	12.0	7.9	3.9
32°	76.0	63.2	52.0	42.5	34.6	27.9	22.1	17.0	12.4	8.1	4.0
33°	76.4	63.8	52.7	43.3	35.4	28.6	22.7	17.5	12.7	8.3	4.1
34°	76.8	64.4	53.5	44.1	36.1	29.2	23.2	17.9	13.0	8.5	4.2
35°	77.1°	65.0°	54.2°	44.8°	36.8°	29.8°	23.8°	18.3°	13.4°	8.7°	4.3°
36°	77.4	65.5	54.8	45.5	37.5	30.4	24.3	18.7	13.7	9.0	4.4
37°	77.7	66.0	55.5	46.2	38.1	31.0	24.8	19.2	14.0	9.2	4.5
38°	77.9	66.5	56.1	46.8	38.7	31.6	25.3	19.6	14.3	9.4	4.6
39°	78.2	66.9	56.6	47.5	39.4	32.2	25.8	20.0	14.6	9.6	4.7
40°	78.4°	67.4°	57.2°	48.1°	40.0°	32.7°	26.3°	20.4°	14.9°	9.8°	4.8°
41°	78.7	67.8	57.7	48.7	40.5	33.3	26.7	20.7	15.2	10.0	4.9
42°	78.9	68.2	58.2	49.2	41.1	33.8	27.2	21.1	15.5	10.2	5.0
43°	79.1	68.6	58.7	49.8	41.6	34.3	27.6	21.5	15.8	10.4	5.1
44°	79.3	68.9	59.2	50.3	42.2	34.8	28.1	21.9	16.1	10.5	5.2
45°	79.5°	69.2°	59.6°	50.8°	42.7°	35.3°	28.5°	22.2°	16.3°	10.7°	5.3°
46°	79.6	69.6	60.1	51.2	43.2	35.7	28.9	22.6	16.6	10.9	5.4
47°	79.8	69.9	60.5	51.7	43.6	36.2	29.3	22.9	16.9	11.1	5.5
48°	80.0	70.2	60.9	52.2	44.1	36.6	29.7	23.2	17.1	11.3	5.6
49°	80.1	70.5	61.2	52.6	44.5	37.0	30.1	23.5	17.4	11.4	5.7
50°	80.2°	70.7°	61.6°	53.0°	45.0°	37.5°	30.4°	23.9°	17.6°	11.6°	5.8°
55°	80.9	71.9	63.2	54.8	46.9	39.3	32.2	25.3	18.7	12.4	6.2

line as it should be. If your dial has a thick gnomon, use two parallel noon lines spaced one gnomon thickness apart, and measure the angles on each side from the appropriate noon line.

Siting the dial outside calls for something to hold it in place under any weather conditions. The design and construction are up to you, but the dial must stay level and the gnomon must point true north.

The Vertical Dial

There's a variant on the horizontal dial in which the plate is vertical. Lay out the hour lines by this formula:

$$A = \text{arc tan}\ [(\cos L) \times (\tan H)].$$

The letters mean the same as before.

Hour Angle	Tangent
7.5°	0.1317
15°	0.2679
22.5°	0.4142
30°	0.5774
37.5°	0.7673
45°	1.0000
52.5°	1.3032
60°	1.7321
67.5°	2.4142
75°	3.7321
82.5°	7.5958

In this design, the gnomon still points to the celestial pole, but since the plate is upright, the angle between the gnomon edge and the plate is equal to:

$$90^\circ - \text{your latitude.}$$

When you mount this type of dial, take care to see that the dial plate is truly vertical and facing directly south. If the wall where you intend to mount it — a house or garage, say — doesn't face directly south, then angle the dial out from the wall.

The Polar Dial

In the two previous designs, the dial plate was a flat board placed either level or vertical. Let's explore another type of dial in which the dial plate is tipped so that one axis of its face lies parallel to the Earth's axis. This design is usually called the "polar" or "equatorial" model. (See diagram on page 50.)

Laying out the lines on a polar dial is different from that of a horizontal or vertical one. Since the shadow-casting edge of the gnomon is parallel to the face of the dial, the shadow it throws will be too. Thus, the hour lines are also parallel to the gnomon and don't converge.

To place the polar dial's hour lines, use the following formula:

$$D = T \times \tan H$$

where D is the distance from the base of the gnomon to the hour-line,
T is the gnomon's height, and
H is the Sun's hour angle.

The chief drawback to this design is that it can't show time close to 6 a.m. or 6 p.m., since at those hours the Sun's rays are parallel to the face of the dial. You'd need an infinitely long dial plate! The practical time limits for this type are from 6:30 a.m. to 5:30 p.m.

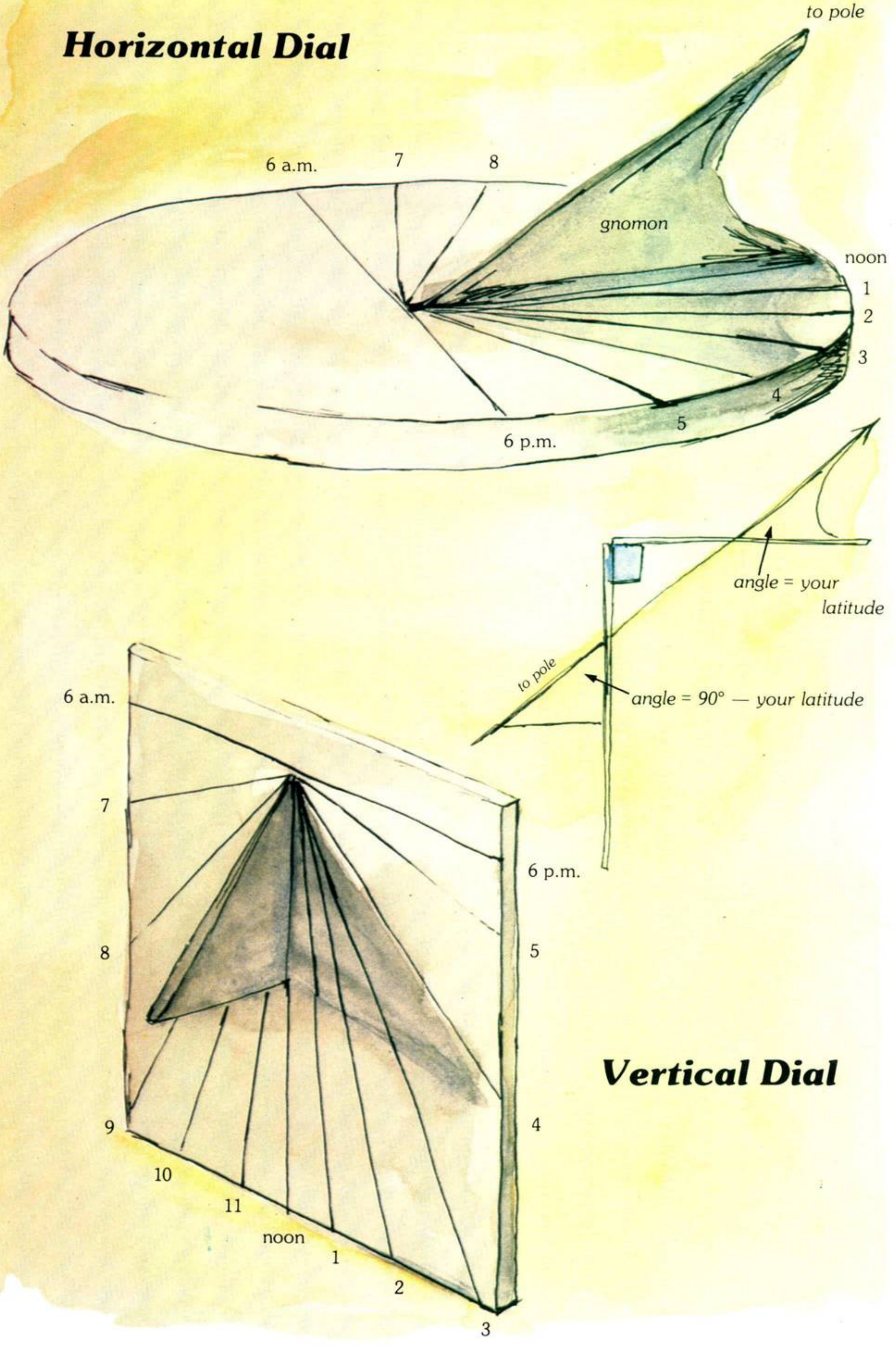
You also need to consider how large you want it to be. The table in the small box on this page gives tangents for every 7½° of hour angle. As you multiply the height of your gnomon by the tangent of the particular hour angle to get the distance the hour line is from the noon line, the height you pick for the gnomon will fix the dial's length.

For example, with an hour angle of 82½° (the angle for 6:30 a.m. or 5:30 p.m.), the tangent is 7.596. This makes a dial with a 1" high gnomon over 15" long. Therefore, in constructing one of these dials, you might do best to run the problem backward, that is, decide on how long you want the dial plate to be and let this determine the height of the gnomon.

The Armillary Model

If you imagine bending the flat dial

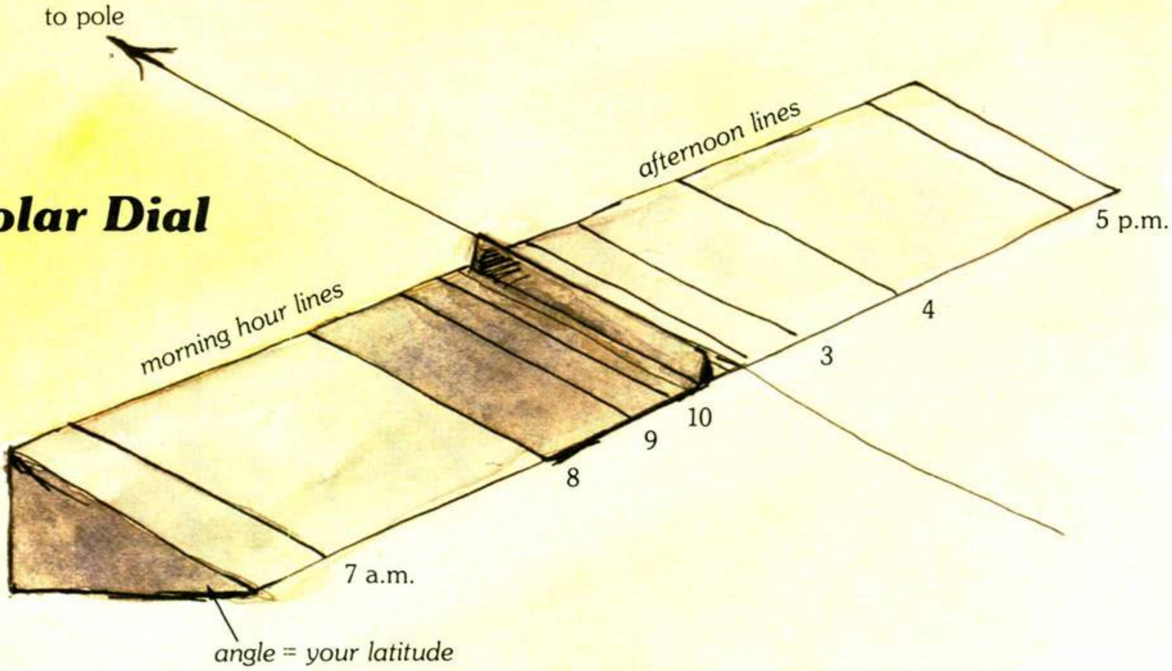
Horizontal Dial

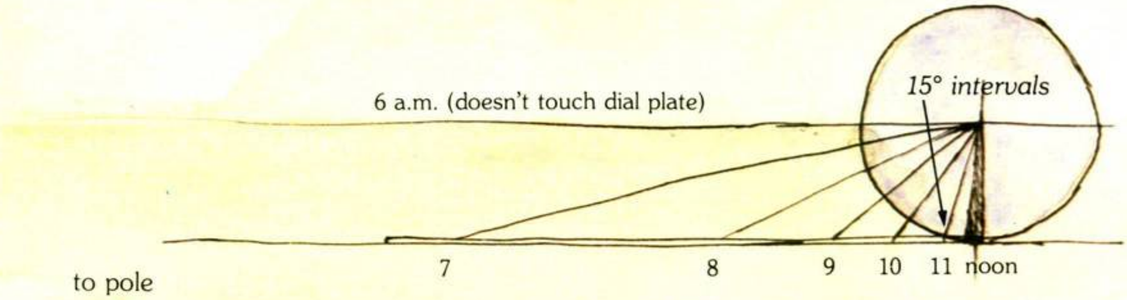


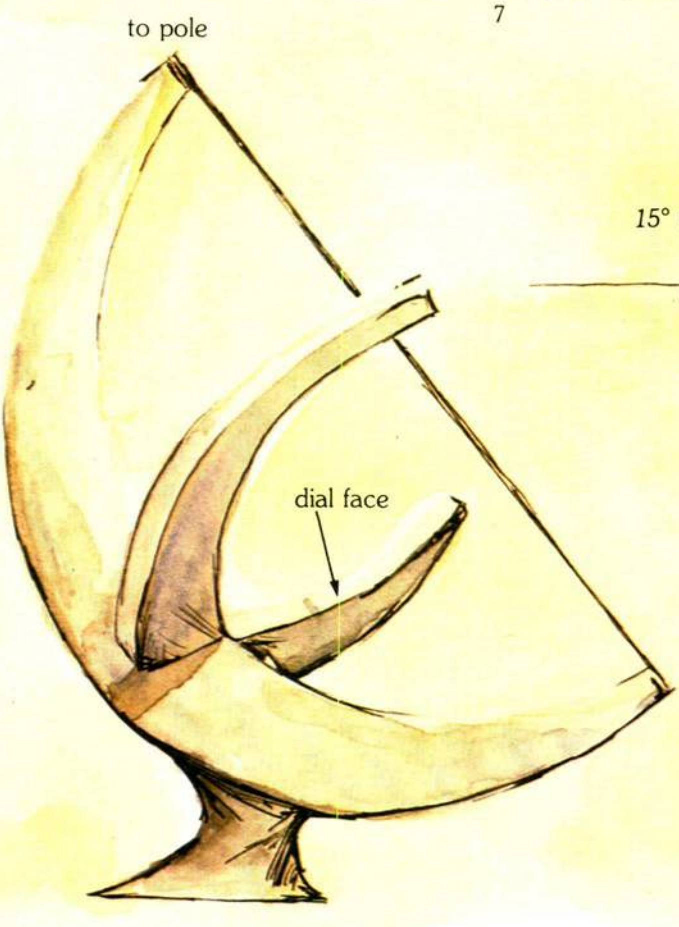
to pole
6 a.m.
7
8
gnomon
noon
1
2
3
4
5
6 p.m.
angle = your latitude
to pole
angle = 90° — your latitude
6 a.m.
7
8
9
10
11
noon
1
2
3
4
5
6 p.m.

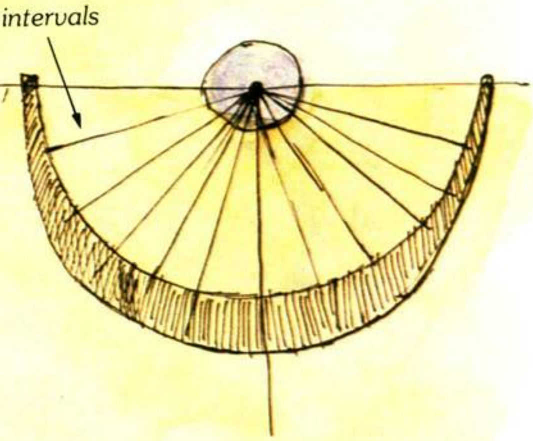
Vertical Dial

Polar Dial


to pole
afternoon lines
5 p.m.
4
3
morning hour lines
10
9
8
7 a.m.
angle = your latitude


15° intervals
6 a.m. (doesn't touch dial plate)
7
8
9
10
11
noon


to pole
dial face


15° intervals

"Armillary" Dial

plate of a polar type into a semicircle with the gnomon's edge at the center, you'll get an "armillary" dial. (Real armillary dials are usually spherical and attempt to show much more than just time. On one you'll find represented the ecliptic, solar declination limits, and the like.)

This dial is certainly harder to construct (since it involves curved surfaces), but carefully made, they are perhaps the handsomest of all sundials.

The spacing of the lines is exactly even (assuming the shape is a true semicircle) with the hour lines precisely 15° apart. The actual distance on the ring, of course, depends on its size. If you're using a flat piece of metal and wish to scribe the lines before it's bent to shape, divide the length into 12 equal parts using 13 lines (this gives a line for 6 a.m. and 6 p.m.). The radius the ring should be bent to is given by:

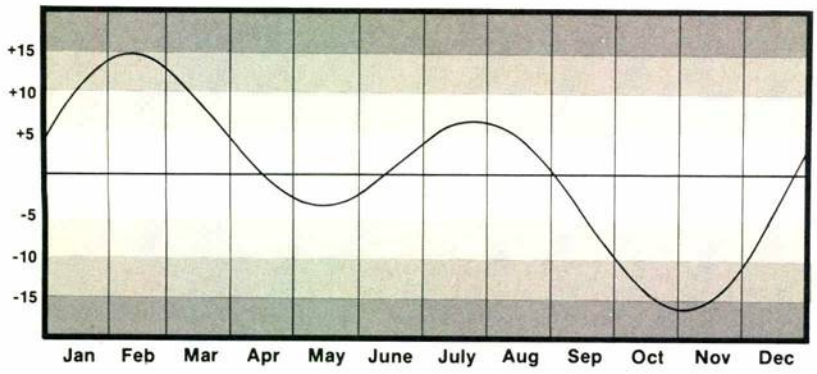
$$R = L / 3.14$$

where R is the radius, and
L is the ring's length.

Very little has been said so far about materials and designs, and that's been quite deliberate. Sundials can and have been made from everything; what you choose is your decision. The same goes for such details as shape, size, colors, etc. Since the essence of "sundialness" is merely a surface, a shadow-caster, and some applied geometry, the bounds of the possible stretch pretty wide — so let your imagination go.

If you're stuck for a design, want to try the geometrical approach, or just feel like marveling at what other people have cooked up, take a look through one or two of the books listed in the box at left. Some or all of them may be in your local library.

— *Robert Burnham*



the equation of time

The graph above shows the continuously varying correction which must be added to the apparent time shown by the dial (when the correction is on the + side) or subtracted from it (when it's on the - side). This correction is called the "equation of time" and results from the Earth's orbit not being perfectly circular.

doing it by the book

"Dialling" (as it used to be called) has always been popular, for what else can account for the great number of books that have been published on the subject? The flood started virtually with the invention of printing and you can rely on a new book or two appearing every few years. Below are some of the recent ones; those more comprehensive are marked with an asterisk.

The Great Sundial Cutout Book, Robert Adzema and Mablen Jones, Hawthorn Books (1978).
**Sundials*, Frank Cousins, Pica Press (1969).
A Choice of Sundials, Winthrop W. Dolan, Stephen Greene Press (1975).
Sundials, Roy K. Marshall, Macmillan (1963).
**Sundials*, R. Newton Mayall and Margaret W. Mayall, Sky Publishing (1973).
**Sundials*, Rene Rohr, University of Toronto (1970).
**Sundials*, Albert E. Waugh, Dover (1973).

for accuracy freaks only

The first thing to remember about dials is that the time they show is local apparent time, not standard time for the zone in which you live. (See "Telling Time," ASTRONOMY, July 1978.) On rare occasions, the two may coincide, but during most of the year, dial time will be ahead or behind clock time by some amount.

To correct for this, three adjustments need to be made: 1) daylight saving time, 2) correction to your standard time meridian, and 3) the equation of time. (Sound horrendous? Don't worry; they aren't. But it's easy to get confused if you don't follow through them step-by-step.)

Daylight saving time is the easiest correction to make. When it's in force, just add an hour to what the dial says; that's all there is to it.

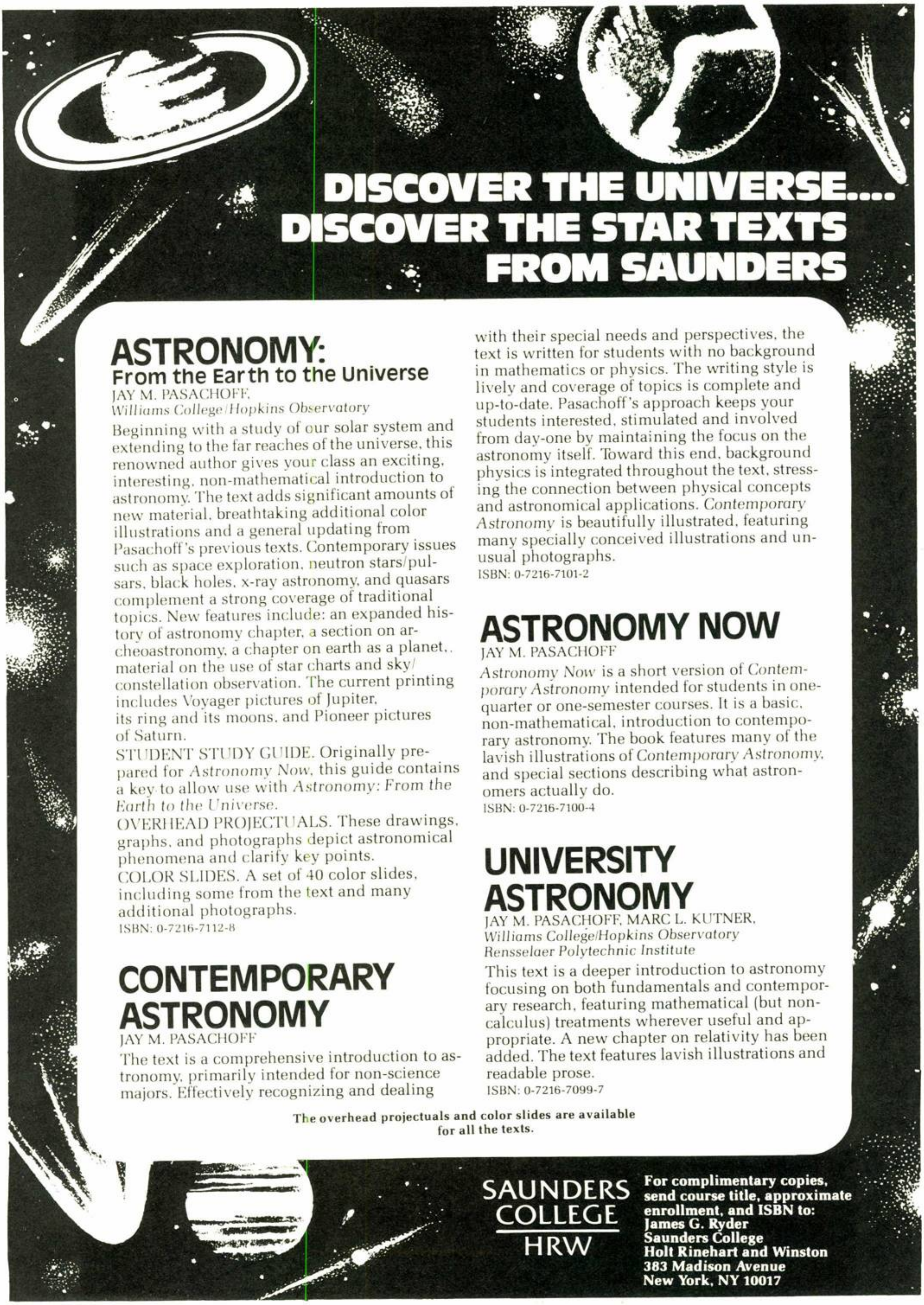
Correcting to your standard time meridian is a bit more difficult. You'll need to know the longitude of your sundial and that of your time zone meridian (EST uses 75°; CST, 90°; MST, 105°; PST, 120°; AHST, 150°). Subtract your longitude from the longitude of the time zone; if the result is a *positive* number, you live *east* of your zone meridian and your sundial is reading *fast*. If you get a negative number, you are west of the zone meridian and the dial reads slow.

By how much? Since 1 hour = 15°, each degree of longitude represents a time difference of 4 minutes. If you live in the central time zone and your longitude is 87°, for example, your dial always reads 12 minutes fast, so you'd subtract those 12 minutes.

The correction for the equation of time requires the most fiddling of all. Although the Earth rotates at a uniform speed throughout the year, our orbit around the Sun isn't a perfect circle. As a consequence, the speed of the Sun's motion across the sky varies according to the season. And this obviously affects your sundial.

The graph on this page shows what the correction is. The sign (+ or -) tells you what to add to or subtract from the dial time to make the correction to clock time.

When you add all three of these corrections together, your dial will be reading correct clock time. Depending on how well you made it, you can get accuracy to within a minute or two.



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JAY M. PASACHOFF,
Williams College/Hopkins Observatory

Beginning with a study of our solar system and extending to the far reaches of the universe, this renowned author gives your class an exciting, interesting, non-mathematical introduction to astronomy. The text adds significant amounts of new material, breathtaking additional color illustrations and a general updating from Pasachoff's previous texts. Contemporary issues such as space exploration, neutron stars/pulsars, black holes, x-ray astronomy, and quasars complement a strong coverage of traditional topics. New features include: an expanded history of astronomy chapter, a section on archeoastronomy, a chapter on earth as a planet,, material on the use of star charts and sky/constellation observation. The current printing includes Voyager pictures of Jupiter, its ring and its moons, and Pioneer pictures of Saturn.

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Williams College/Hopkins Observatory
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estimating magnitudes

gazer's
gazette

by
Raymond E. Zit

If you haven't *looked* for a variable star, chances are you haven't seen one. Variables are one of the subtle sights in the sky because they change slowly. Precisely because of the slowness of their changes, variables weren't even known in the West until 1596, when the long period variable Omicron (*o*) Ceti, or Mira, was discovered.

Discoveries were few and far between. The variability of the eclipsing star Algol, possibly known as a "winking" star by the Arabs, was noted in Europe in the 1670s. In 1784, John Goodricke, an Englishman, discovered that Delta (*δ*) Cephei also varied.

Delta Cephei is an excellent "first" variable for an observer with absolutely no equipment. You can determine its period and light curve simply by making and recording nightly estimates.

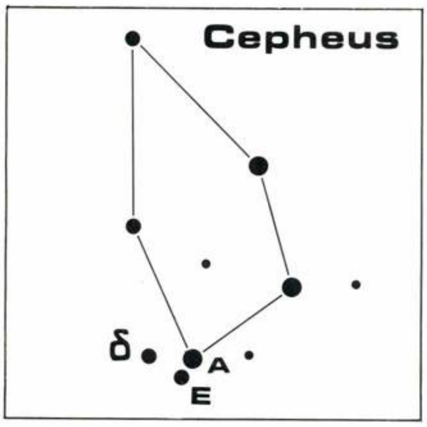
At right, you'll find a map of this star and two comparison stars nearby. Delta and the comparison stars form an easy-to-recognize triangle. All three stars are readily visible without optical aid. If you locate them in the sky this evening, you can make your first variable star estimate.

How? It's simple: one of the comparison stars is labeled "A", and the other is labeled "E". Imagine that these letters refer to their brightness. Since Delta is usually between them in brightness, it could be called "A", "B", "C", "D", or "E". Look at the three stars carefully, fixing the "A" and "E" in your mind, then choose the letter that best represents the brightness of Delta.

If you think it's midway between the comparison stars, call it "C". If it's closer to "A", call it "B". If it's the same as "E", call it "E". It'll take about two minutes. Record the date, time, and your estimate in a notebook.

Keep After It

After two or three weeks of nightly observation whenever it's clear, you'll notice that Delta is bright some nights, dim some nights, and in between on others. Plot all your observations on a sheet of graph paper — your estimate versus the date. If you have had perfect weather every night, your observations will show a fairly clear pattern of bright to dim to bright about every five days. Depending on how many cloudy nights you had, however, you might not see any pattern at all. But it's there, so have patience. Continue observing and recording your estimates every clear night. You'll feel inspired having seen that the star really *is* variable.



However inspired you feel, try to put the previous night's observation out of your mind when you make an estimate, otherwise you'll bias the "data set" you're accumulating. Don't plot your results every day; it's too tempting to fudge your estimates.

After about two months you'll be ready to plot all your observations again. Try to spot two times of maximum light, one near the beginning and one near the end of your observing run. Estimate or count the number of cycles that have occurred (this is difficult, so your first estimate may be wrong).

Divide the interval (i.e., the number of days) between two obvious maxima by the number of cycles between them to find the period of variation. Divide the graph into cycles of that length by making a mark to show the beginning of each cycle; then trace all the observations from all the cycles onto one master sheet of tracing paper. This will combine your entire data set into one light curve.

If the graph shows nothing but a scatter of points, you've guessed the number of cycles wrong, so the period you chose was wrong. Try again with another number of cycles.

If a rather clear curve emerges as you "fold" all the data together, you've probably got the right period. The curve is a light curve for a Cepheid variable star, a type of variable that pulsates regularly. Delta Cephei is the prototype of the class, which is why they're called Cepheids.

Getting More Serious

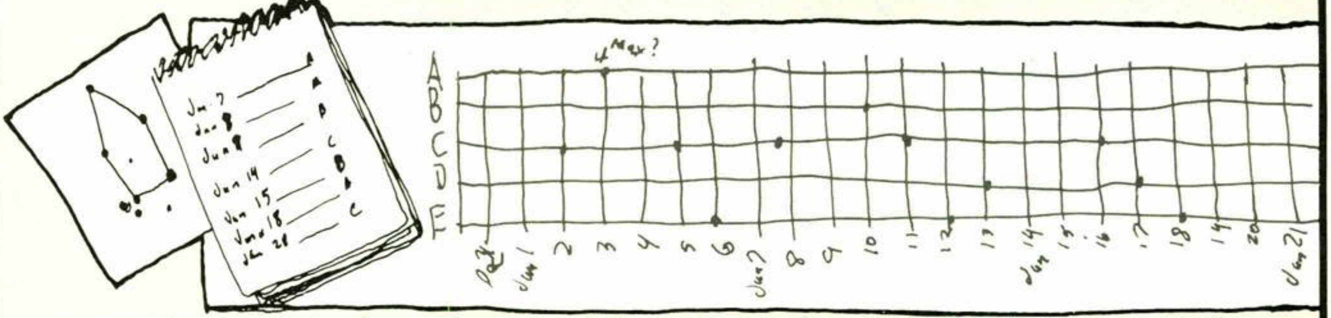
If you own your own telescope, you're a valuable commodity. How so? Consider the fact that advanced as well as beginning stargazers have made a valuable contribution to the astronomical world in their observation of variable stars. In fact, for some of us variable star observing has become the basis for our involvement in astronomy.

A large portion of the published light curves of variable stars exists because of visual estimates made by dedicated amateurs. In the United States, the American Association of Variable Star Observers (AAVSO) is the primary recipient of data from these energetic observers — hundreds of them, all watching those stars that change.

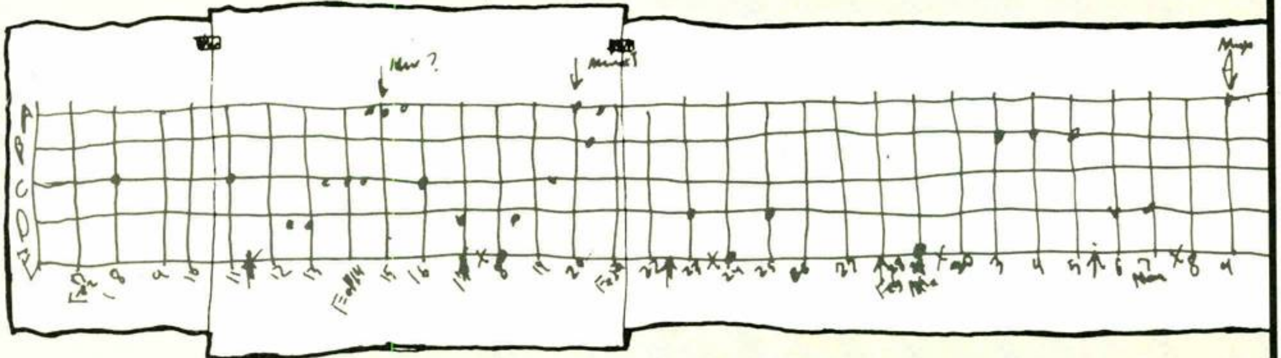
All well and good, you say, but isn't visual work very much less accurate than measurements made with a photometer? Besides how valuable can my little estimate be? You'd be surprised.

Experienced observers can estimate

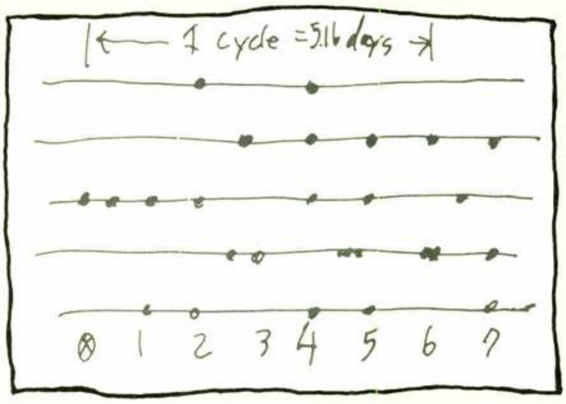
Plotting the Curve of δ Cephei



After you've accumulated several months of observations in your notebook, plot them up on a long chart made of sheets of graph paper taped together.

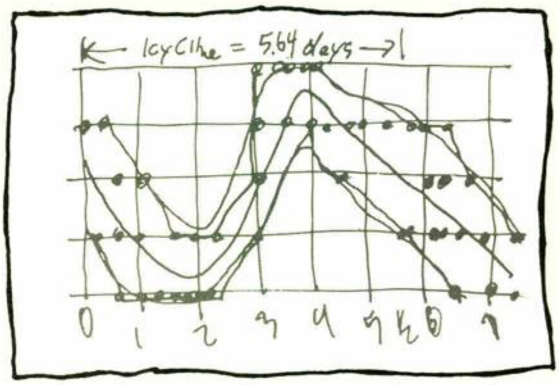


Now study the data. You should be able to spot several maxima, or times of greatest brightness, separated by intervals that are multiples of five to six days.

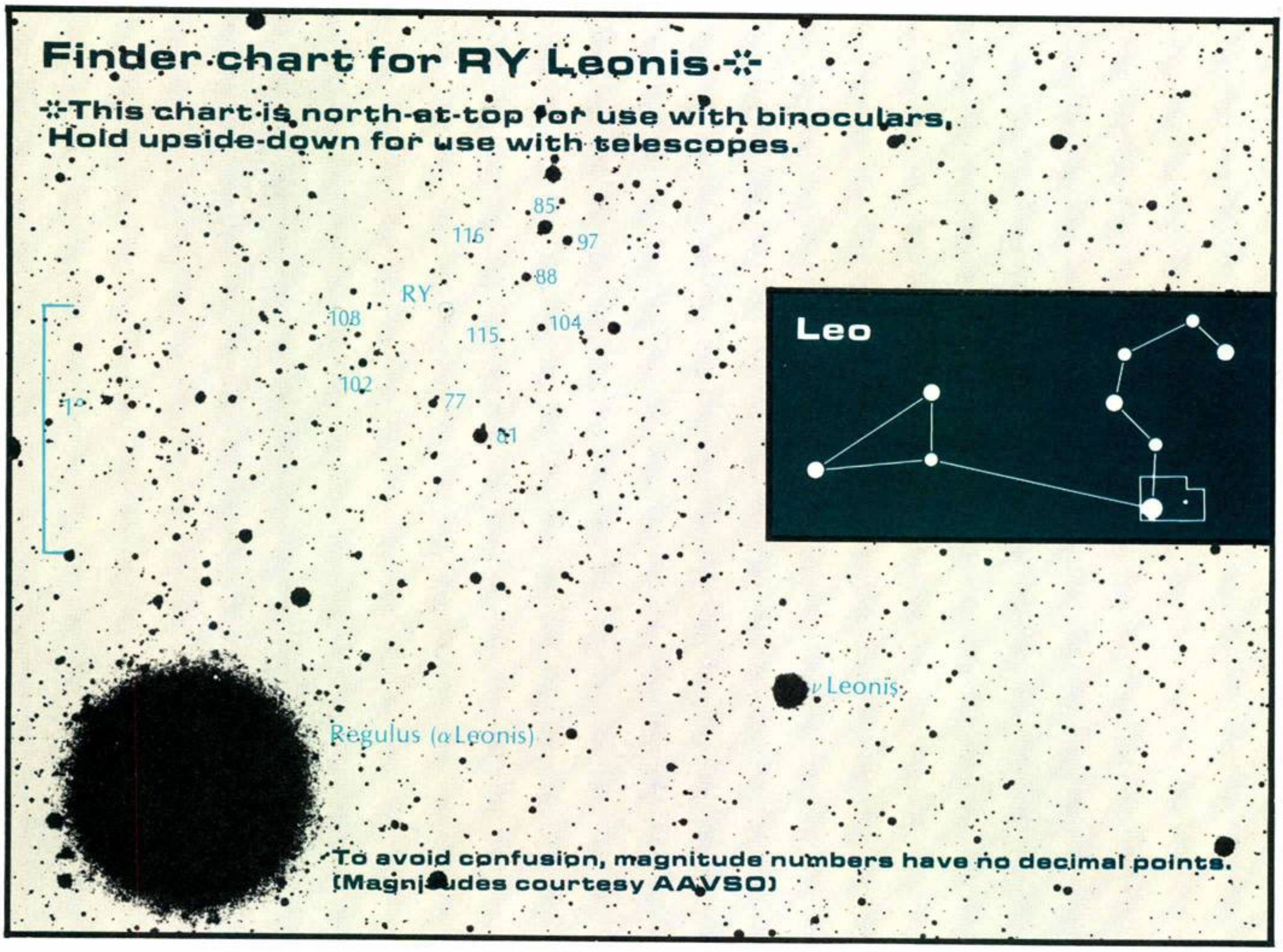


If there are two clearly defined maxima separated by 62 days in your data, there could be 10, 11, 12, or even 13 complete cycles between. Mark off the 62 days into 12 cycles of 5.17 days each. "Fold" all your data onto a single cycle by tracing them. Does a light curve emerge from the estimates? If it doesn't, the estimate is probably wrong.

Now try again. Perhaps there were 11 complete cycles of 5.64 days each. Test your guess by marking the graph every 5.64 days, and again tracing the data points onto it. Line up the zero point on the tracing paper with each hypothetical maximum. This time, a clear, if somewhat scattered, light curve has emerged from the observations.



What is the real period of Delta Cephei? You can determine that yourself. Write us when you've got an answer.



Finder chart for RY Leonis ⁘

⁘ This chart is north-at-top for use with binoculars. Hold upside-down for use with telescopes.

To avoid confusion, magnitude numbers have no decimal points. (Magnitudes courtesy AAVSO)

to 0.3 to 0.5 magnitudes — reliably. Even if you're a newcomer not yet skilled at it, you're still in the ball game. When the estimates from lots of observers are averaged, some very good and some not so good, they even out. A single line can be drawn to describe the variation of the star in question, as you did for Delta Cephei.

If you've attempted making visual estimates before, you could have been very easily turned off. Variable observations require a lot of patience. With practice, however, you'll become an effective estimator as your brain stores experiences encountered at your telescope and you make use of your own built-in photometer — you'll soon formulate a mode of operation and develop a technique. Simply stated, the star and stargazer will be in harmony.

Until you become expert enough to make quick magnitude judgements while observing, try a second approach. The idea is simple: forget the actual magnitudes of stars and substitute an arbitrary scale of your own. Instead of using letters, though, use whole numbers.

This system will become clearer as you observe a star and give the system a tryout. A six-inch telescope is just about the right size, and we'll use the variable star RY Leonis as a test example. It has a range of almost three magnitudes, from 8.7 to 11.5.

You'll see lots of good comparison stars on the chart. Let's use six of them. "But which six?" you ask. A quick look at the variable will tell you which stars to use and which not to, depending on whether RY is faint or bright. Let's say it's in the middle somewhere and we want the 8.5 star and the 11.6 star to be the start and end of our scale.

Set the scale up in this fashion: call the 8.5 magnitude star a 10, and so on as follows: 9.7 = 20, 10.2 = 30, 10.4 = 40, 10.8 = 50, 11.6 = 60. Forget about the other values for now.

Look at RY. What do *you* say it is? If you feel the star really is near the middle of this scale then it has to be given a number. It's not as bright as 20, nor as dim as 30. After eyeballing it, you feel it's about 25 or 26.

Well, is that good enough? The answer is: "Yes!" Even if RY really has a value of 29 on your scale, a guess of 25 or 26 is very good for a new observer. (In my years of observing, I have known only two individuals who felt their estimates were consistently accurate to two or three-tenths of a magnitude.)

Don't worry about errors you might have made. Time at the telescope will increase your efficiency and accuracy. Since all observations are valuable, record what you see regardless of whether you're afraid of discrepancies in your observations.

You now have two variable star projects you can follow for a while. One is a bright star you won't even need a telescope to follow, and the other is a nice telescopic variable well-placed for watching this spring. When you're out observing, spend a few minutes each evening and check in with your stars.

Take It Easy

Even if you get interested in observing lots of variables and join the AAVSO, don't make a numbers game out of variable star observing. Strive for quality, not quantity, and enjoy it. Decide what type of stars you want to study and set up a modest program — 25 stars is a good size. But most of all, enjoy yourself. Happy observing!

Ray Zit has been observing variable stars at the Milwaukee Astronomical Society's observatory for over 15 years — and to date has made nearly 4000 estimates. He is currently Observatory Director.

ASTRONOMY
REVIEWS

Shuttle: the world's first spaceship
Robert M. Powers
230 pages, paperback, $10.95
Stackpole Books (1979)

Anyone buying this book to learn the how, why, and wherefore of an incredibly complex rocket/spacecraft/aircraft is going to be sorely disappointed.

Powers is a competent wordsmith; he has a knack for making the material he presents interesting and lively. However, in this book he has taken the tack of many a freshman confronted with an essay test question he can't handle: If you can't answer the question, write copiously on something you *can* discuss.

Consider his comparison of Apollo and Shuttle: "The biggest difference of shuttle is the *method* of travel: launch like a rocket, maneuver in space like a spacecraft, and land like a conventional airplane." That statement occurs three sentences after this: "Orbiter is as unlike Apollo as a DC-3 was unlike a Sopwith Camel, perhaps a slightly unfair comparison. (Apollo wasn't quite that primitive and the DC-3 wasn't quite that sophisticated.)" The three sentences between tell us that Shuttle pulls 1/3 the g's during launch and entry and provides a shirtsleeve environment (which Apollo also did).

That's all — in 230 pages of text liberally interlarded with press-kit illustrations, two appendices (more Public Information Office handouts), and an index — that Powers has to share with us on the differences between Apollo and Shuttle.

He doesn't even seem to appreciate all his handouts. One photo shows John Young and Bob Crippen (crew for the first Shuttle orbital flight) in the Mission Simulator cockpit. The caption, in its entirety, reads: "Astronauts are trained in the flight deck of a full-scale shuttle orbiter mockup (Courtesy NASA)." Of all the illustrations in the book, by the way, that is the only one that shows an orbital vehicle configuration instead of the Approach and Landing Test version. Several illustrations are upside down.

Of the total 230 pages, 65 address such things as astronaut corps history, astronaut selection, a smattering of scientific satellite history, Spacelab (to be flown on Shuttle, but an entirely separate program), other payloads, and various "upper stages" to be used with Shuttle. Another 60 pages are devoted to post-1990 concepts. There's also a 12 page chapter describing some space activities and related musings between A.D. 180 and the present. About 10,000 words directly bear on Shuttle and its systems.

The technical information that is covered is factually correct. Extraneous "local color" about Cape Canaveral and environs is flagrantly wrong for the most part. On the other hand, errors of omission are far more serious.

In his foreward to this book, Michael Collins says, "Once the two gigantic solid rocket boosters ignite, the Shuttle is utterly dependent on them, with no escape rockets to pull it free in case of danger. On the first flights, the two-man crew will be provided ejection seats, but when the crew grows to four or seven, the ejection seats will be removed, and from then on, the solids simply must not fail."

That is the real essence of Shuttle: America is adopting an airline concept of manned space operations after a handful of orbital flights by a brand new vehicle — a brand new vehicle more complex than any ever flown before.

Powers doesn't mention this, let alone tell how it will be done. The errors of omission on the hardware level are similar. He alludes to the solid rockets, but doesn't give their size, thrust, or the reasons for their use. Nothing is said to hint that Shuttle's main engines are the most sophisticated ever built. He completely ignores the fact that the Air Force will own and operate several Shuttles and will mount an ambitious program of their own. Here's the description of entry: "For landing, the Space Shuttle simply uses the orbital maneuvering system to deorbit, and then flies down to a landing on its landing gear."

In attempting to write a book on the Space Shuttle, Powers has let his reach magnificently exceed his grasp. *Robert W. McNenny.*

Astroblemes — Cryptoexplosion Structures
G.J.H. McCall, editor
437 pages, hardcover, $39.50
Dowden, Hutchinson & Ross (1979)

Astrobleme literally means "star-wound," and is the term given to geological features on the Earth that were likely caused by meteorite impact. With some cases, like Arizona's Meteor Crater, there's no doubt at all as to what the origin was. Other examples are less clear, and the spectrum runs on to include some very weathered and eroded structures whose origin is perhaps more guesswork than knowledge.

This book is a collection of important professional geological papers on the topic published between 1960 (about when they were first recognized as a class of objects) and three or four years ago. The general reader is going to run into a lot of jargon (some will like this; others won't), and of course familiarity with basic geology is assumed. Yet even those untutored in the subject can skim through the book and pick up a feeling for what is going on. This is a "library browsing" type of book, and enjoyable at that.

Mathematical Astronomy With a Pocket Calculator
Aubrey Jones
254 pages, hardcover, $15.95
John Wiley & Sons (1979)

For the astronomically-minded person, the arrival of pocket calculators has eliminated a lot of tedious arithmetical drudgery and given them a chance to do some number-crunching never attempted otherwise. Jones' book provides routines for calculating many basic astronomical matters such as positions of Sun, Moon and planets, correction of precession, comet orbit ephemerides, etc. The first half of the book explains the steps in the calculations; the second provides specific programs for HP-25 and HP-67 programmable calculators. Those with algebraic-logic machines (programmable or un-) can use the first half to derive algorithms for their own machines.

A New Sun: the solar results from Skylab
John A. Eddy
198 pages (illus.), hardcover, no price given
NASA (1979) [order as NASA SP-402 from the Government Printing Office, Washington, D.C. 20402]

This superbly-illustrated book summarizes the knowledge gained about the Sun from observations with the ATM (Apollo Telescope Mount) aboard Skylab. Eddy first reviews what we knew about the Sun before space observations became possible via satellite, and then spends most of the book describing first the hardware and then the observations themselves. The text's level of presentation is about that of ASTRONOMY, and should present no adult reader with difficulties; children (and others of course!) will also be fascinated by the strange and beautiful false-color images.

The Rocket
David Baker
278 pages, hardcover, $17.95
Crown (1979)

Unlike many "coffee-table" books which are largely distinguished by lavishness of illustration and utter banality of text, this is a welcome change. Baker has assembled a good and useful history of rockets. Sensibly, he has kept the emphasis on work done in this century, much of it perforce military. He has also dug up a great many photos seldom seen before.

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AstroNews

Cosmic Rays May Come From Supernovae

The first clear evidence of isotopic anomalies in matter coming from outside the solar system has been found in cosmic rays by University of Chicago astrophysicists. Their results may help determine how elements are formed in stars and help locate the source of cosmic rays — electrons and atomic nuclei that have been accelerated to high velocities in space. Though discovered early in the century, their origin is still hotly debated.

Moises Garcia-Munoz, John Simpson, and Paul P. Wefel reported in the September 15 *Astrophysical Journal Letters* that cosmic rays entering their earth-orbiting instrument contained at their source three times as many nuclei of the element neon with atomic weight 22 compared with neon of atomic weight 20 as are found within the solar system. Most of the neon in the solar system, and probably in the galaxy, has an atomic weight of 20; its nucleus contains ten protons and ten neutrons. The isotope of neon called neon 22, however, contains twelve neutrons, and because it is formed in processes different from those forming the more abundant neon 20, its prominence gives clues to the type of processes that create cosmic ray particles.

Lick Observatory Photograph

The supernova which gave rise to the Crab Nebula may also be a source of cosmic rays.

The researchers could compare cosmic ray neon 22 to that in the solar system thanks to recent observations by Simpson and William F. Dietrich, who used an identical detector aboard a different satellite to measure the neon 22 in solar flares. Simpson and Dietrich reported earlier that the amount of neon 22 in solar flares, and hence in the Sun, is about one-eighth the amount of neon 20 present. This neon 22 abundance is also identical to that found in some ancient meteorites, implying that the abundance of neon 22 within the solar system may not have changed for the last four billion years.

Simpson explains that over the wide range of cosmic ray energies, from a million to a billion-billion electron volts, several different sources and mechanisms of acceleration may be involved. Whatever whips cosmic rays to their near-light speeds must be some of the most energetic — and interesting — processes in space. By comparison, the nuclear fires of Earth's Sun, as intense as they are, fall far short of the energy needed to create and propel a cosmic ray.

According to Wefel, "the various elements in cosmic rays can be explained by either of the two most popular theories for cosmic ray origin, formation in the interstellar medium or formation in supernovae. Isotopic ratios are more informative, and the isotopic ratio we find for neon seems to imply that supernovae are involved in at least some stage of cosmic ray formation."

The abundance of neon 22 points to supernovae in two ways. First, cosmic rays now reaching Earth were created and accelerated not much more than twenty million years ago. Yet the interstellar medium seems not to have contained much neon 22 for several billion years, so cosmic ray nuclei drawn from the gas between the stars should not show an excess of neon's heavy isotope. Second, neon 22 is readily formed in the thermonuclear fires of those stars most likely to blow up in supernova explosions, spreading the heavy isotope across the galaxy, perhaps in the form of cosmic rays.

Finding the ratios of the neon isotopes is more complicated than simply separating the two and counting the number of each that enters the cosmic ray telescope. Cosmic rays are the most energetic, fastest moving particles ever found. Some of them hurtle through space with a million times more energy than the particles in man's most powerful accelerators. Yet they are electrically charged and spend millions of years traveling through the galaxy, so despite their great energy, they are gradually deflected by the magnetic fields of the galaxy and the Sun. Garcia-Munoz explains that the cosmic ray telescope's orbital height of 35 earth radii is great enough to prevent the Earth's magnetic field from interfering with the progress of the cosmic rays entering the telescope.

Wefel says that getting cosmic rays into the solar system is a little like trying to throw cards into a hat on a gusty day. Most of the cards will be blown off course, but sometimes one thrown in the right direction and with adequate velocity will enter. Similarly, cosmic rays with inadequate velocity to withstand the forces of the magnetic fields they traverse will not reach the same destination as their higher-energy counterparts.

The magnetic deflection discriminates between the two isotopes because the masses of neon 20 and neon 22 differ by about ten percent. Although the two have identical electric charge and experience the same force from a magnetic field, neon 20 will deflect more, because it is lighter and has less inertia. The deflection can make neon 20 appear depleted at its source, when it is merely filtered out by solar magnetic fields.

The researchers also accounted for fragmentation — the breaking up of nuclei when they collide in interstellar space. For example, the neon nuclei in cosmic rays can split apart to form two smaller nuclei, such as carbon and beryllium, while heavier nuclei can split to form new neon and other elements. The measure of both neon isotopes must be corrected for this "secondary" production before the amount of each isotope at its source can be determined.

From its orbit 200,000 kilometers above Earth, the cosmic ray telescope collected more than one-half as many nuclei of neon 22 as neon 20; after correcting for the various effects in interstellar space, the researchers found that neon 22 was still 40 percent as common as neon 20 at the source of the cosmic rays. The solar system contains only about thirteen percent as much neon 20 as the more common neon 22.

To help extend their results, the researchers are now measuring the abundances of heavy isotopes of magnesium and silicon, both of which may be related to the neon abundance and may provide more clues to the formation of cosmic rays.

Gravity Wave Research

The California Institute of Technology has completed negotiations for a joint research program in the field of gravity wave research with Moscow State University. The protocol calls for scientific exchange and cooperation between a group of physicists working with Caltech Professor of Theoretical Physics Kip Thorne and a Soviet group working with Moscow State University scientist Vladimir Braginsky.

The two groups will aid each other's work on the theoretical and experimental studies of gravity waves. Gravity waves emanate from extremely violent events in outer space, such as the births of black holes, the collisions of black holes, and supernova explosions. The ability to detect gravity waves would give scientists an unprecedented look at such phenomena, many of which are invisible to optical and radio telescopes.

The Caltech and Moscow groups have carried out joint research informally since 1970, with Caltech providing theoretical input and Moscow developing the experimental devices to detect gravity waves. Now, however, Caltech scientists are beginning to develop their own experimental approach to gravity wave detection, under the leadership of Professor Ronald W.P. Drever. Caltech's increased activity will be enhanced greatly by the new protocol, which will officially provide for the flow of information between the two groups, said Dr. Thorne. The joint research program will consist principally of exchange visits by scientists and the sharing of data.

According to Dr. Thorne, past collaboration between the two groups has resulted in several significant contributions. For example, the Moscow type of gravity wave detector must be able to measure vibrations on the order of one millionth the diameter of the nucleus of an atom to detect the infinitesimal gravity waves that the Caltech group predicts are bathing the Earth. However, the laws of quantum mechanics prevent such tiny vibrations from being measured, even in principle, by current standard techniques. But as a result of their past collaborations, the Caltech and Moscow groups have invented new "quantum nondemolition measuring techniques" which can circumvent these limits. These techniques will be used in most future gravity wave detectors to achieve the sensitivity necessary for gravity wave astronomy.

Index

- Cosmic Rays May Come From Supernovae
- Gravity Wave Research
- Southern California Expands?
- A Galileo for Saturn?
- Space Telescope Institute
- Cygnus A or a Turkey?
- Asteroid Spaceship
- A Jovian Earth
- Planets of Double Stars
- Astronauts and the Space Telescope
- Sun-Earth Investigations

Southern California Expands?

Measurements carried out independently by research investigators of the U.S. Geological Survey and NASA indicate that Southern California has entered a phase of rapid increase in its area of land surface. Radio noise from distant quasars — powerful celestial objects — helped pinpoint the change.

Dr. A. E. Neill, scientist at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California and member of the laboratory's Astronomical Radio Interferometric Earth Surveying Project Team, reported an increase in distance of 20.3 centimeters (8 inches) in seven months between the Pasadena laboratory and the NASA Goldstone Deep Space Station, about 193 kilometers (120 miles) to the northeast.

Neill described the team findings at a session of the fall meeting of the American Geophysical Union in San Francisco. J.C. Savage of the Geological Survey reported, in the same session, results which are consistent with the project team's measurements.

The project team's method of measurements involves recording radio noise from distant quasars simultaneously at the two radio telescope locations. By comparing the time of arriving signals, using extremely precise clocks, changes in distance between the telescopes from one survey to the next can be measured to accuracies of 5 cm (2 inches) or less. The techniques have been developed to the point that such measurements can be used to detect strains over large blocks of the Earth's crust and may have important application to the earthquake prediction mission of the Geological Survey.

Between 1974 and 1978, Geological Survey crews measuring some 250 lines of about 32 km (20 miles) each in length found that all the changes in length recorded were consistent with a uniform north-south contraction of Southern California. The lines are measured to an accuracy of better than 1 cm (½ inch) using laser beams.

Since 1978, however, the pattern has changed with networks of lines in the Salton Sea and Coachela Valley areas showing extension east-west. At Palmdale, California, about 56 km (35 miles) north of Pasadena, the transition from north-south contraction to extensional strain has been more dramatic. Between May and October of this year the land surface has expanded in area by about 2 parts per million. Over an area of about 24 by 32 km (15 by 20 miles) the change would amount to the addition of a quarter acre of land to the Palmdale area in six months.

The extension of 20.3 cm (8 inches) over the distance from Pasadena to Goldstone is in approximate agreement with the laser measurements but suggests that the area of expansion may be much larger, perhaps extending over 161 km (100 miles) to the northeast.

There is the appearance from NASA project team data that a similar episode of extension occurred in 1975. However, Geological Survey networks along the San Andreas Fault throughout Southern California showed opposite data, that of compression.

The period over which such precise measurements have been made is less than a decade. From such a short period of data acquisition, scientists are as yet unable to determine whether or not the present pattern is simply one phase of a cycle of compression and expansion.

The suddenness and size of the expansion is intriguing, but as yet, not well understood. There have been other hints in recent years that such large regions of the Earth's crust deform episodically, but the six-month period of this large extensional distortion is considered remarkable.

The implications for future earthquakes are speculative and scientists such as Dr. Barry Raleigh of the Geological Survey are prepared only to say that the present pattern of straining, if it persists, is likely to lead to a large earthquake on the San Andreas Fault much sooner than would the earlier pattern recorded of a north-south contraction.

Both the Geological Survey and NASA, which sponsor the team project, have increased the frequency of measurements in the area and plan continued close cooperation in these studies.

A Galileo for Saturn?

With the Pioneer 11 encounter with Saturn past and the two Voyagers on their way to the solar system's second largest planet for an even better look, NASA has already begun looking at the possibilities for a detailed study of the saturnian system in the 1990s.

The mission study, now in its third year, is being conducted jointly by the Jet Propulsion Laboratory and NASA's Ames Research Center. The Japanese Institute of Space and Aeronautical Science is also participating in the definition of options for analyzing the upper atmosphere of Saturn and Titan, the solar system's largest moon and the only one with an extensive atmosphere.

Since the Saturn mission would not be launched from the Space Shuttle until 1988 or 1989, current definition of the mission is very preliminary. Nevertheless, it seems highly likely that the spacecraft will be composed of at least three main elements: a Galileo-type orbiter designed to "tour" the saturnian system for an extended length of time, an atmospheric probe to be sent into Saturn itself, and a Titan probe.

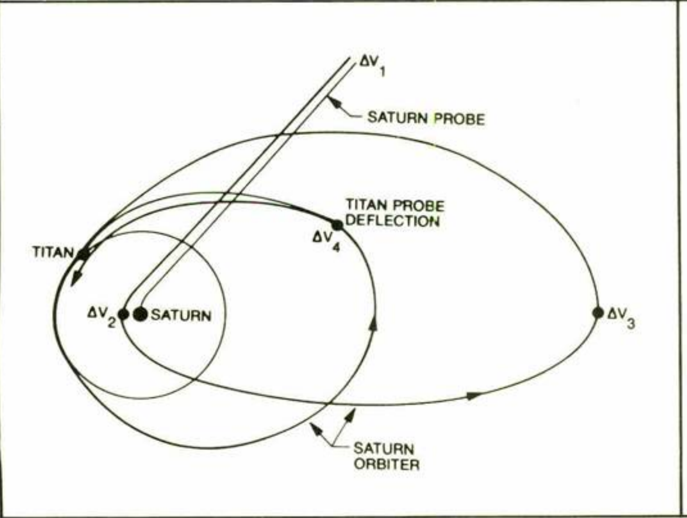
The Saturn probe would separate from the main spacecraft about 60 days before encounter and radio data up to the orbiter for 40 to 60 minutes as it enters Saturn's atmosphere. Immediately after the Saturn probe entry, rockets would be fired aboard the orbiter to boost it into orbit about Saturn. Titan would be first examined close-up 170 days later, and the Titan probe released on its entry trajectory 60 days after that. 240 days after the original Saturn encounter and Saturn probe entry, the Titan probe would enter the giant satellite's atmosphere and perhaps touch down safely on the surface, while the orbiter flew by, relaying data to Earth.

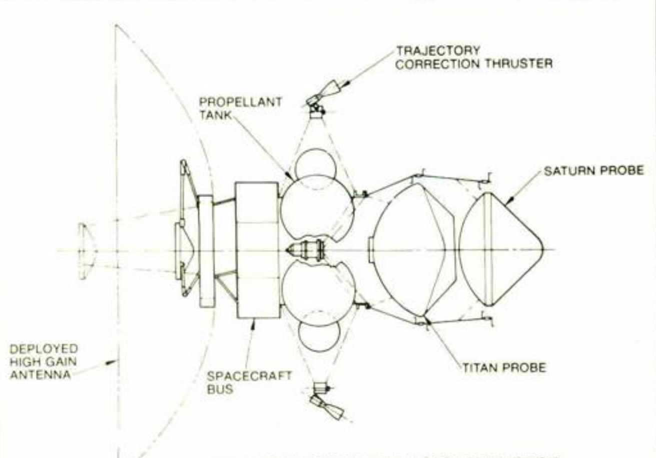
Three alternative options for the Titan probe are currently being studied. The first would involve only entry and examination of the atmosphere. The second and third would include extensive pre-entry measurements and either limited (second option) or extensive (third option) examination of the surface. A final decision will probably be based on weight constraints, since the first option would require a probe of only about 113 kilograms, while the third would push the weight up to over 350 kilograms. The Saturn probe would probably weigh about 210 kilograms, a little less than the Jupiter probe included in the Galileo mission.

A number of other options are also being studied at this stage. There are two alternative flight trajectories from Earth to Saturn, for example, one of which involves gravity assists in two subsequent Earth encounters and a long period of low thrusting from a solar electric propulsion unit, while the other involves a conventional high-energy launch followed by a ballistic trajectory with a single Earth-gravity assist.

Both options would result in an Earth-Saturn flight time of eight years, but the first could deliver nearly twice as much spacecraft mass to Saturn. The first, however, is dependent on the availability of the Solar Electric Propulsion System (SEPS), originally designed for use in the Halley/Tempel 2 Comet Mission. The Office of Management and Budget has recently cut funding for development of the SEPS from NASA's budget. If this project is not restored this year, the two-comet mission will be out, and the first trajectory option for the proposed Saturn mission (with its much higher delivery capability) imperiled.

The total mission lifetime after arrival at Saturn, including a tour of Saturn's satellites, could be as long as three years. Such is the vast scale of the solar system and the time required for its exploration that the entire mission, from Shuttle launch to the final transmission of data from the saturnian system, would last at least eleven years.





CUT-AWAY SPACECRAFT CONFIGURATION

Space Telescope Institute

Proposals for the establishment of a Space Telescope Science Institute facility in the United States have been received by NASA. The Institute will be a national facility for the receipt and evaluation of data from the 20,000-pound Space Telescope, and is scheduled to be fully operational in the early 1980s.

Located on a site to be chosen by the winning contractor, the Institute will be responsible for the selection and support of observers using the telescope, and for detailed science planning and scheduling, routine console operations, data storage, calibration, and analysis.

The contractor will staff the facility with scientists to manage the various science programs and perform related astronomical research. In addition, all personnel and facilities necessary to house and support principal investigators and general observers are to be provided.

The 2.4-meter (96-inch) Space Telescope is scheduled to be placed in a 310-mile-high orbit by the Space Shuttle in late 1983 or early 1984. Circling the Earth above the obscuring atmosphere, the telescope will be capable of observing some 350 times more volume of space than can be seen now from ground-based observatories. With its immense capability, the Space Telescope is expected to be one of the most important astronomical tools for the remainder of this century.

Science and spacecraft data will be transmitted via a Tracking and Data Relay Satellite to the control center at the Goddard Space Flight Center in Huntsville, Alabama, and then sent on to the Telescope Institute for processing and analysis.

The Space Telescope is expected to function at least until the end of the century. At about 30-month intervals, the Space Shuttle will visit the telescope in orbit where astronauts will perform maintenance and replace scientific instrumentation. Occasionally, the entire observatory may be returned to Earth for major refurbishment. This is expected to occur at about five-year intervals. The ground refurbishment will take about one year, and then the telescope will again be placed in orbit by the Shuttle.

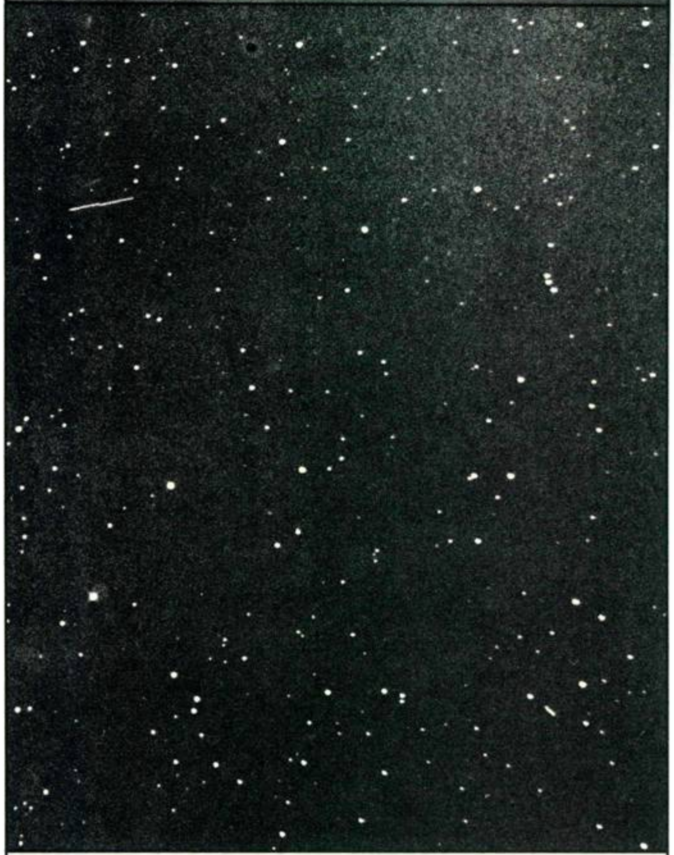
Cygnus A or a Turkey?

A new form of environmental pollution with an impact on modern astronomy may have been uncovered by three British astronomers at the Radio Astronomy Laboratories at Jodrell Bank, England. The pollution is in the form of radiation leaking from the microwave ovens so popular in modern kitchens.

The researchers, Brian Anderson, Bob Pritchard, and Barrie Rowson, reported in the December 6, 1979 issue of *Nature* that their tests of several microwave ovens showed that a radio telescope could detect leaking radiation from the ovens at a distance of fifteen miles. While the major part of the radiation emitted by microwave ovens occurs in the licensed portion of the spectrum which does not affect radio astronomy, there is apparently some leakage of radiation at other frequencies which are important to astronomers. And while the seals on microwave ovens were shown to be effective in shielding in the primary radiation, the much lower intensity extraneous emissions leak out readily. Though this radiation would not be harmful to humans, the researchers calculate that it could raise the background noise level of a radio telescope operating at 1.4 gigahertz (GHz) by twelve times, and could interfere with 10% of radio observations.

The astronomers propose that new regulations prohibit ovens "if the amount of the emitted radiation ouside the licensed band of 2450±50 GHz can cause harmful interference to authorized radio services" — which means radio astronomy. The International Telecommunication Union has reserved certain bands for use by radio astronomers, and it is these bands which the British astronomers say are being threatened by the operation of microwave ovens in the vicinity of radio telescopes, such as those at Jodrell Bank.

Asteroid Spaceship



The Rev. Ronald Royer and Steve Padilla took the above photograph on November 21, 1979. The trail at upper left is of an asteroid newly discovered by Eleanor Helin of Caltech on November 15, designated 1979 VA, which has a rather peculiar orbit. (The deliberate northward shift during the hour-long exposure enables us to determine that the object is moving eastward.) Its eccentricity is 0.627, with an orbital period of 4.25 years. At first, 1979 VA was thought to be an Alinda type asteroid, that is, one whose orbit has been stabilized with a period exactly one-third that of Jupiter. It may be that instead 1979 VA is moving toward an orbital resonance with Jupiter, and its orbit may oscillate around the resonance period of 3.95 years. At present, 1979 VA's orbit takes it from about the distance of Earth from the Sun (one astronomical unit, or 1 AU) out to 4.25 AU, less than 1 AU from the distance of Jupiter's orbit — which makes 1979 VA virtually a natural spaceship! The other asteroid trail in the lower right of the picture is that of 1149 Volga, not that of a missile sent to destroy 1979 VA.

A Jovian Earth

Could the Earth have formed in the middle of a giant protoplanet something like Jupiter? Is the solar system, with its relatively small, rocky planets close to the Sun and large gaseous planets farther away from the Sun, typical of planetary systems around other stars?

Many scientists think the answer to both questions may be yes, and recent computer simulations strengthen this view and include a major role for giant protoplanets. Answers to these questions are essential for discovering planets around other stars and charting the history of the solar system.

A team of scientists at NASA's Ames Research Center in Mountain View, California, has shown that giant protoplanets would have been orbitally stable in the early solar system. They also have developed a formula for determining sizes and positions of planets in planetary systems in general. They are now looking for likely arrangements of planets around other stars.

One of the most frequent explanations of solar system formation is that at some time very early in the solar system's history a number of giant gaseous protoplanets revolved around the young and growing Sun. These giant protoplanets may have had the same mass as Jupiter, but were larger in size and hence more diffuse. The Ames researchers suggest that the rocky material in these giant protoplanets rapidly (within a few thousand years) fell to the center of the protoplanets, forming rock cores. The mass of such a core would be comparable to one Earth mass.

The Pioneer Jupiter and Saturn spacecraft have produced evidence for the existence today of such rocky cores in the giant gas planets Jupiter and Saturn.

As the Sun grew to its present mass by the infall of material from a primordial cloud of gas and dust, its gravitational field would have become stronger. Eventually, it would be strong enough to strip away the atmospheres of the giant protoplanets, leaving behind only their rocky cores. These remnant cores, it is argued, are the present terrestrial planets.

If Venus, Earth, and Mars are in fact the remnant rocky cores of giant gaseous protoplanets like Jupiter, these protoplanets would have had to be stable for at least a thousand years.

The NASA-Ames team has shown that two Jupiter-mass protoplanets orbiting the Sun in the present-day orbits of Earth and Venus would, in fact, be stable for several thousand years. If the masses of the protoplanets were increased substantially (four times Jupiter's mass), then the one in Venus' orbit would have been ejected from the solar system in a few decades.

For these findings the team used a computer code designed to calculate accurately the orbital motions of a model planetary system. They also found that much more massive protoplanets (many times Jupiter's size) could have existed in stable orbits in the region of the outer gas giants, Uranus and Neptune.

A dramatic finding was that the orbits became unstable very suddenly. This meant catastrophic ejection of a planet from the solar system, with the body suddenly sailing off on a tangent trajectory.

Earlier, Dr. P.E. Nacozy (University of Texas) showed that an instability catastrophe might exist. Therefore, the team looked for a simple way to tell whether a particular type of planetary system would be orbitally stable.

They ran numerical experiments in a large computer, a CDC 7600, to model several types of possible planetary systems. Surprisingly, they found that the stability of planetary systems depends mainly on the ratio of orbit sizes (the ratio of their distances from the large parent body, the Sun). Stability is not affected by how close or how distant individual planets are from each other.

The Ames team now is attempting to develop a set of mass and orbit-ratio categories to describe planetary systems revolving around other stars than the Sun. No other planetary systems have yet been found, but sophisticated new methods of search are on the drawing boards.

Calculations, like those by the NASA-Ames team, will help scientists to locate planetary systems around other stars, and to determine whether such systems occur frequently or whether the solar system is a rare phenomenon.

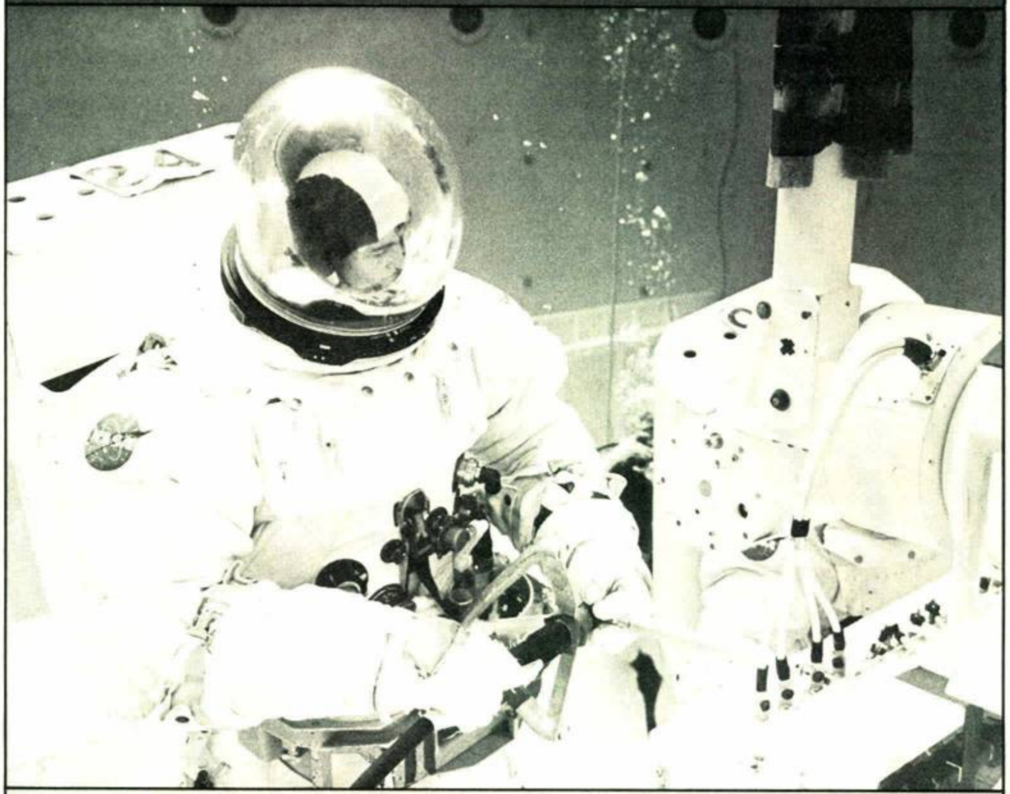
Planets of Double Stars

A common setting for some science fiction stories is the planet of a double star. This gives an author the opportunity for some colorful writing describing the different-colored shadows cast by the double suns. But is such a planetary system realistically possible? Can planets have stable orbits in a double star system? It seems they can.

Soviet astronomers in 1977 reported the possible detection of a planetary body in the binary system 61 Cygni. Following that, Robert S. Harrington of the U.S. Naval Observatory in Washington, D.C., did a mathematical study of the three-body system in which one object is of planetary size and the other two are stellar in mass. Harrington's study shows such a system would be quite stable — under certain conditions.

Harrington applied his conclusions to the solar system we live in. Suppose, instead of the Sun we know, we had a double star in which each sun was half the mass of the Sun and separated from each other by a distance of about .4 astronomical unit (37 million miles). In such a solar

Astronauts and the Space Telescope



Dr. Shannon Lucid, a mission specialist astronaut, uses a power tool on a full-scale mockup of a portion of the Space Telescope submerged in a huge 1.3 million gallon water tank facility (known as a Neutral Buoyancy Simulator) at NASA's Marshall Space Flight Center in Huntsville, Alabama, as part of a project to evaluate crew stations for servicing the telescope in Earth orbit. Dr. Lucid, of the Johnson Space Center in Houston, Texas, recently became the first woman astronaut to work in the simulator, which allows a close approximation of a zero-gravity environment. (Distortion caused by the curvature of the plastic helmet makes the astronaut's head appear smaller than normal.) The Space Telescope, to be placed in orbit by the Space Shuttle, is being developed under direction of the Marshall Center.

system, Mercury would be thrown out of orbit and into interstellar space. The orbital eccentricity of Venus would be slightly affected. But the rest of the planets, including Earth, would be undisturbed.

As another example, Harrington replaced Jupiter with another star identical to the Sun. In this case, only Mars would be thrown out of the solar system. But the rest of the inner planets would remain unaffected.

In both cases, Harrington reported, the "zone of habitability" for the solar system would be unaffected. Life could still exist on Earth.

Sun-Earth Investigations

NASA is asking scientists to propose experiments for a program of coordinated satellite measurements designed to provide a better understanding of the near-Earth space environment and Sun-Earth relationships. The program, called Origins of Plasmas in the Earth's Neighborhood, would attempt for the first time to examine the collective behavior of specific components which make up the geospace system — the near-Earth interplanetary medium, magnetosphere, ionosphere, and upper atmosphere.

An understanding of this system is a prerequisite to understanding Sun-Earth relationships and their effect on our planet's environment, including short and long-term weather and climate prediction and the impact of solar phenomena on communications. Current understanding, gained from previous satellite programs, clearly shows a high degree of interaction between all the different geospace components.

Basically, the program's aim is to investigate the flow of mass, momentum, and energy through the solar wind and electrified environment near Earth, using instrumentation for remote sensing and close-up measurements of electromagnetic radiation, fields, particles, and plasmas (electrified matter).

The program calls for simultaneous observations from a minimum of four spacecraft, placed in specific key regions of space and operating in widely different orbits. The satellites, launched by the Space Shuttle over a one-year period in the mid-1980s, would be placed to observe each of the major geospace plasma source regions (solar wind and ionosphere) and storage regions (ring current, plasma sheet, and distant geomagnetic tail). Each spacecraft would have significant orbit-change capability to provide observational flexibility and permit exploration of a vast volume of geospace. The spacecraft would operate for at least four years.

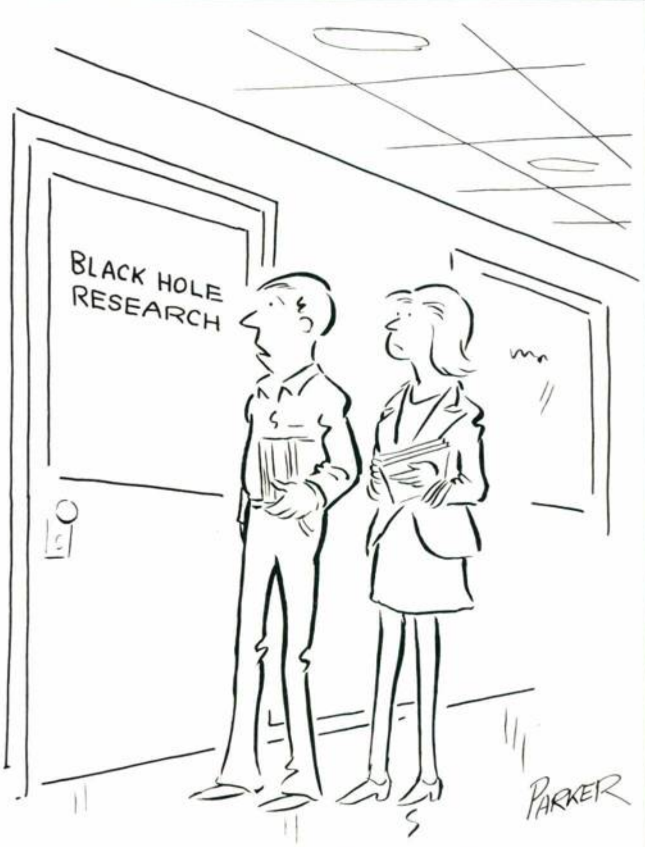
Although the program has not been authorized by Congress, scientists have been asked to submit their proposals in order to ensure maximum scientific participation in the program and design of the spacecraft.

Objectives of the proposed mission would be to:

- Understand the physical process controlling the origins, entry, transport, storage, acceleration and loss of electrified matter, and electrical current in the Earth's neighborhood.
- Understand cause-and-effect relationships among the closely coupled solar wind, magnetosphere (the magnetic envelope that surrounds Earth), and the ionosphere (the electrified part of the atmosphere).
- Trace the flow of matter and energy through the geospace system from their interplanetary or atmospheric origins to ultimate deposition into the atmosphere or loss to the interplanetary medium.
- Assess the importance to Earth's environment of variations in energy deposition into the atmosphere caused by plasma processes.
- Utilize the unique capabilities of the program for solar wind and other studies.

This will be the first program to address the geospace environment as a whole. Past observations have been obtained primarily by single-point satellite measurements, and more recently by multi-point measurements designed to study the linkage between no more than two of these significant geospace components.

Program management will be the responsibility of the Solar Terrestrial Division of NASA's Office of Space Science, Washington, DC. Project management is expected to be assigned to NASA's Goddard Space Flight Center, Greenbelt, MD.



All I know is no one who goes in there ever comes out.

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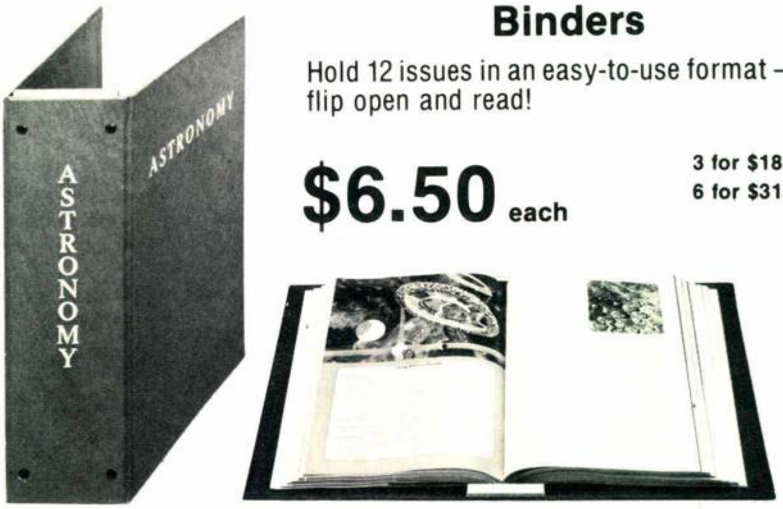

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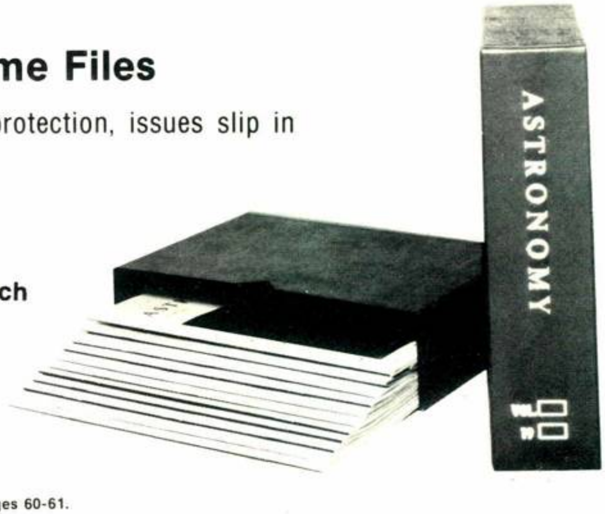

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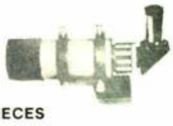

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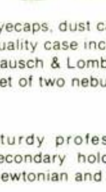

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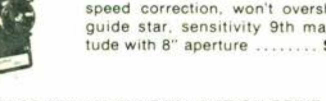

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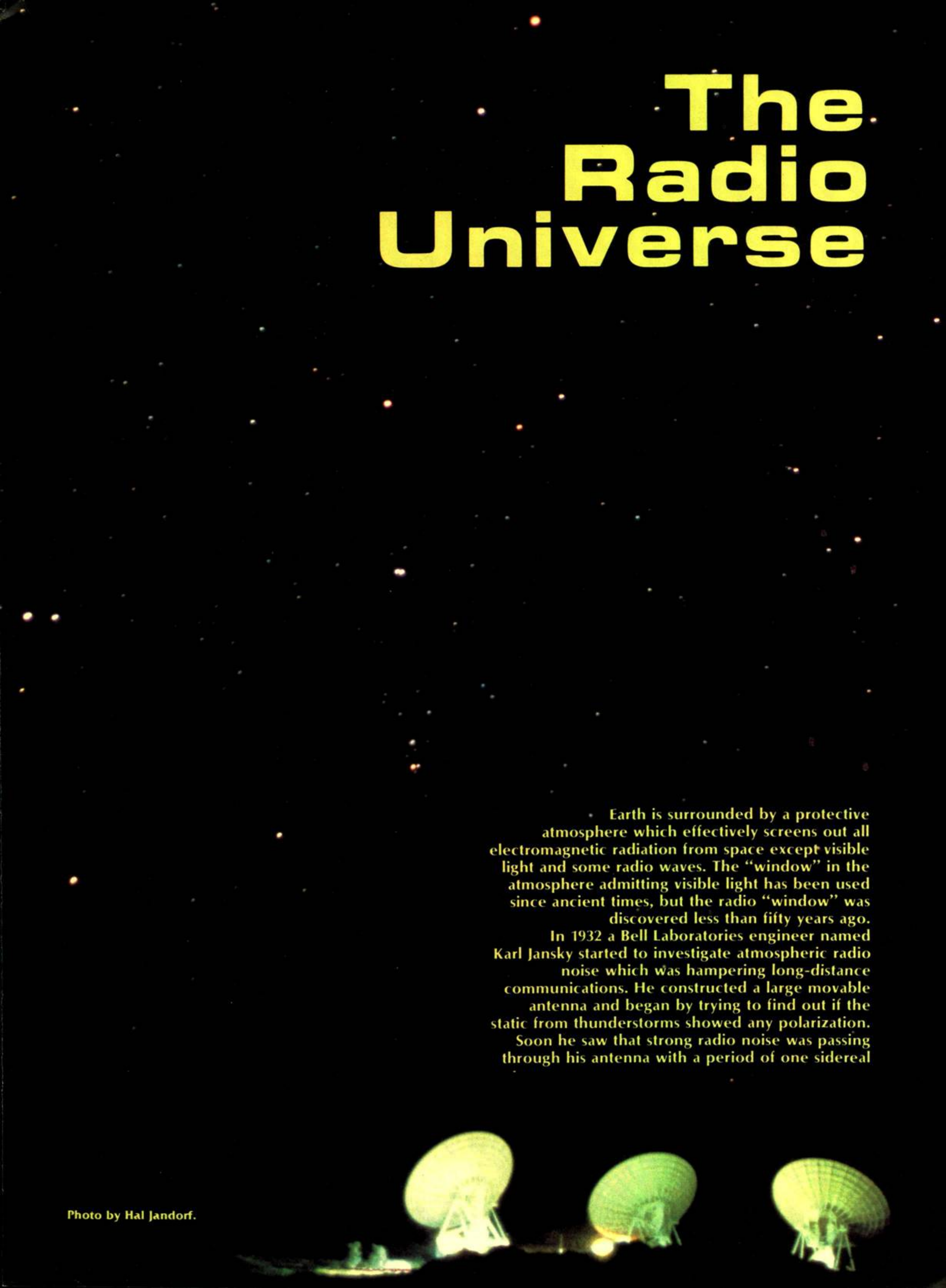
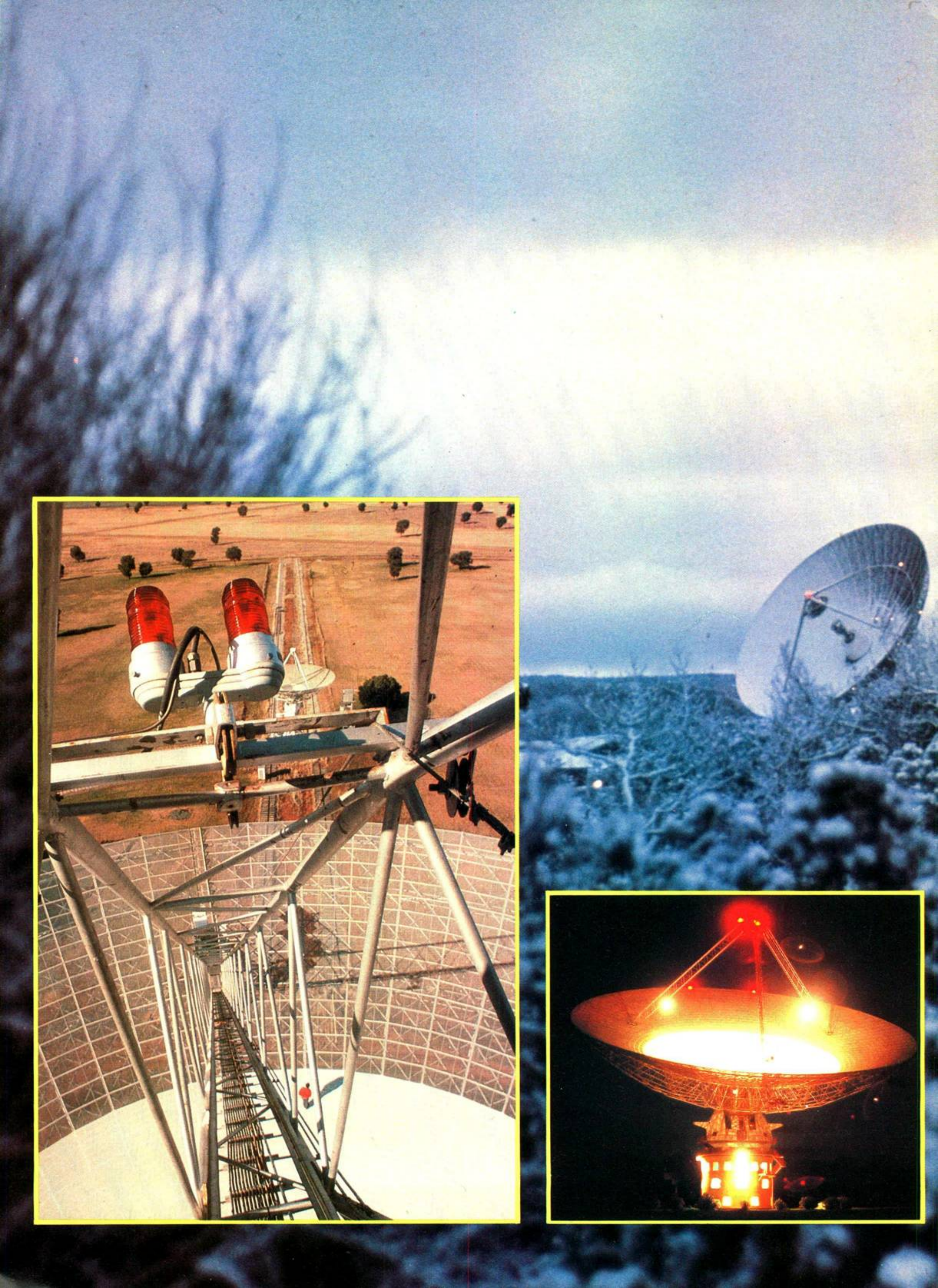


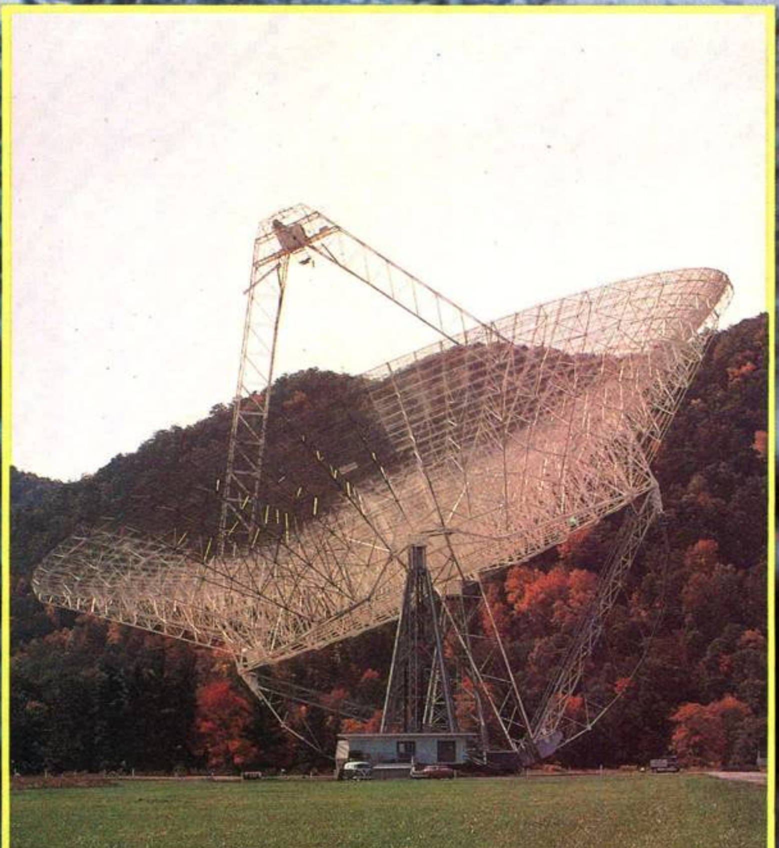
The Radio Universe

Earth is surrounded by a protective atmosphere which effectively screens out all electromagnetic radiation from space except visible light and some radio waves. The "window" in the atmosphere admitting visible light has been used since ancient times, but the radio "window" was discovered less than fifty years ago.

In 1932 a Bell Laboratories engineer named Karl Jansky started to investigate atmospheric radio noise which was hampering long-distance communications. He constructed a large movable antenna and began by trying to find out if the static from thunderstorms showed any polarization. Soon he saw that strong radio noise was passing through his antenna with a period of one sidereal

Photo by Hal Jandorf.





The spidery structures of radio antennas look fragile, yet they must hold their shapes accurately to fractions of an inch, even in high winds. Background: Onsala Observatory's dish in Goteborg, Sweden. Photo by David Shaffer. Below left: Two views of the 210-foot antenna at Parkes, New South Wales. Photos by Jay Pasachoff. Below: The 300-foot dish at the National Radio Astronomy Observatory in Green Bank, West Virginia. Photo by Jay Pasachoff.

day and further experiments showed him that the radiation's source lay in the direction of the center of the Milky Way.

Jansky's discovery excited mild scientific interest, but nothing else was done for almost 10 years. In 1940, an amateur astronomer named Grote Reber guessed that the radio noise might have a thermal origin, and accordingly would be stronger at wavelengths shorter than those Jansky used. So Reber constructed a 30-foot diameter parabolic dish in his backyard and, after some trial and error, prepared the first radio map of the sky.

At approximately the same time, the combatant nations in World War II were exploring the nature of the first-discovered radio star — the Sun — and its effects on military communications. After the war, most of the findings were declassified, so with the help of war-developed electronics, radio astronomy came into its own.

Radio astronomy pursues much the same objectives as optical astronomy: namely, identifying all radio sources and accurately cataloging their positions in the sky and, far more important, uncovering facts to tell us something about the astrophysical processes going on in them. In doing this, radio astronomy has grown in two main directions: *active* and *passive*.

Touching the Sky

Radar, developed during the 1930s, is the active branch of radio astronomy, and its recent successes have been extremely impressive. A pulsed radio signal is beamed through the antenna toward an object. At some later time, the reflected signal comes back, much reduced in strength. When the transit time and frequencies contained in the return signals have been analyzed, scientists can learn much about the object's distance, relative velocity, and surface characteristics.

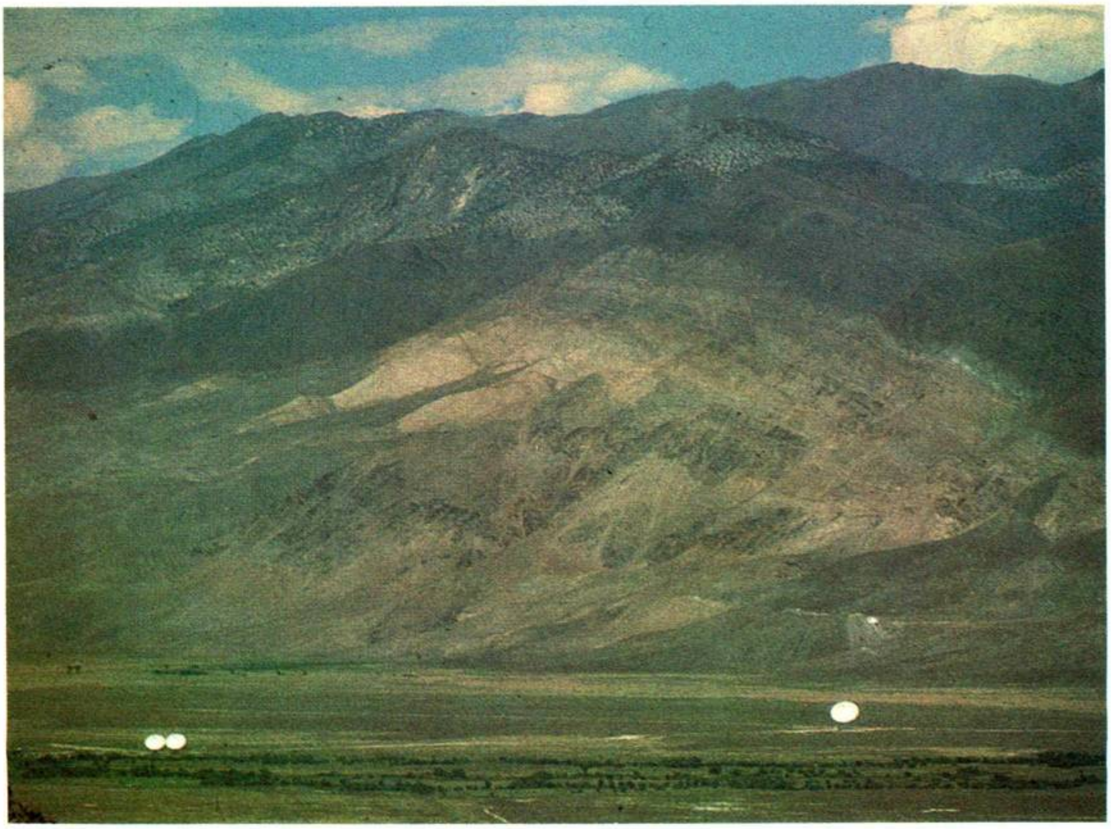
Radar is chiefly useful in the inner solar system because of the comparatively short distances involved. Using it, astronomers have measured the exact distances from Earth to the Moon and to Venus, thus helping to determine the scale of the solar system. Radar has also been used to explore the surface topography and composition of Mercury, Venus, the Moon, and Mars; to probe the outer atmosphere of the Sun; to contact Saturn's rings and the satellites of Jupiter; and to measure precisely the orbital trajectories of meteorites.

Radar helped astronomers prove that meteors and meteorites are true solar system objects — not interstellar wanderers passing through as was once thought. Radar has shown that Venus rotates in a reverse, or retrograde, direction (taking 244 days for one turn) and that Mercury's rotation period was 59 days instead of the long-believed 88 days. Even before Mariner 10 took a look at Mercury, planetary scientists had been tipped off to expect a lunarlike surface there from the characteristics of the radar signals coming back.

From its inauspicious postwar beginnings, radar astronomy really took off with the space age. Instruments, facilities, and techniques all benefited from the massive investments by military and civilian space programs. Outstanding instruments now in use include the 150-foot fully steerable parabolic dish at Stanford University (constructed especially for radar astronomy), the 85-foot dish at NASA's Goldstone Tracking Station in California, the 250-foot fully steerable dish at the Jodrell Bank Observatory in England, and the 1000-foot bowl at Arecibo, Puerto Rico.

Eavesdropping on the Universe

The other — and by far larger — branch is passive radio astronomy. Using an antenna and receiver, radio astronomers detect and analyze the radio emissions of astronomical objects. Just like their optical counterparts, radio astronomers are limited to observing only — they cannot interact with the object. In fact, the analogy between radio and optical astronomy is quite striking. For instance, due to variations in the Earth's atmosphere, radio sources twinkle just like visible stars. Moreover, radio objects show Doppler shifts (due to relative motion between the source and observer) just as optical ones do, and the resulting changes in frequency are easier to detect and measure accurately in radio than they are in the optical



Manmade interference can easily destroy a radio observatory's usefulness, and so they are usually placed in remote areas. Down in the Owens Valley of California, shielded by mountains, is a 3-dish radio interferometer. Photo by Jay Pasachoff.

region of the electromagnetic spectrum.

Radio sources tend to be "discrete" and "individual" (as stars are); sky maps of them can be made. Analogous to the chief activity of yesteryear's positional astronomers, many catalogs of radio objects have been compiled, the most complete being the *Fourth Cambridge (4C) Catalogue*. Radio astronomy even uses the same system of celestial coordinates: right ascension and declination.

But there's a major difference between the optical sky and the radio. Optical astronomers have long recognized dim regions where stars are obscured by huge dark clouds of interstellar dust or neutral hydrogen. Opaque to visible light, these clouds are transparent in the radio region of the spectrum. We can see, in radio, what lies behind them. The important finds, naturally, are the core and inner spiral arms of our own galaxy. In addition, the warm clouds give off their own radio signals, telling us about their structure and the distribution of material inside them. We can thus use radio to explore structure in our own galaxy hidden to optical telescopes.

The Nitty-Gritty Nuts and Bolts

What makes up a radio telescope? While the components are simple (an antenna and receiver), a lot of work goes into their design because they must perform to very stiff requirements.

First, let's consider the receiver. A receiver for astronomical use is much like an ordinary hi-fi receiver, but vastly more sensitive. A typical astronomical signal has an intensity of only a few Janskys (1 Jansky = 10^{-26} watt/Hz impinging on a one-meter square antenna), so the device's sensitivity must be very great. We'd get about one Jansky from a CB radio operating on the Moon.

The main factor limiting their sensitivity is the thermal noise generated in the receiver itself, and cryogenic (low-temperature) techniques are beginning to push the noise threshold even lower. The present limit for detectability is about 250 microjanskys (2.5×10^{-30} watts/m^2/Hz) in the best apparatus. As for the future, masers (the radio equivalent of lasers) can be used to boost the sensitivity of the system, but at the cost of severely reducing the number of frequencies the receiver can pick up.

Next, let's consider the antennas. Their critical factors are their collection area (measured in square wavelengths) and the radiation pattern, that is, how wide is the beam and how directional is its sensitivity? These two qualities correspond to light-gathering ability and resolution, respectively, in an optical telescope.

Because the shortest radio waves have a wavelength 1000 times longer than visible light (and the longest are a billion times longer), antennas must be proportionally larger than optical telescopes to achieve the same performance. Also, a larger collecting aperture creates a narrower beam and increases its directionality, thus cutting down the background noise.

Like the receiver, the antenna also is plagued by the thermal noise of Earth and the antenna structure itself. For this reason, some large radio telescopes use Cassegrain configurations in which the receiving instruments look up at the cool sky thus minimizing the warm-Earth background noise.

How Big Can They Go?

The engineering challenge of shaping these dishes to a tolerance of a tenth of a wavelength and holding to this shape accurately regardless of solar heating of the antenna structure, high winds, etc., isn't trivial, and in fact is the limiting factor in how large they can be made. Practical "fully steerable" dishes can be made up to a few hundred feet across; then the compromises must begin. The biggest dish in the world is the 1000-foot one at Arecibo, Puerto Rico which was carved into a valley and depends on the Earth's rotation for its right ascension scan. By shifting the feed pick-ups to the receiver, scientists can scan across about 20° of declination in the sky, but basically it's a zenith-pointing instrument.

Many astronomers have spent much research on determining the "best" frequencies for exploring the universe. By international agreement, certain frequency bands belong exclusively to radio astronomy, but interference from manmade satellites and terrestrial radio sources such as radar units, remains a major and growing problem.

The work-a-day reality facing any radio astronomer is: external interference, detecting extremely weak signals, absorption at certain frequencies by the atmosphere, and mechanical difficulties of wind, rain, solar heating, etc. The ideal place for a radio telescope is on the far side of the Moon, but the logistics would be murderous!

Getting Big Scope Results from Little Scopes

Budgetary and engineering problems soon bring a halt to ever-bigger telescopes, so astronomers have been forced to try other approaches. One such is to adapt an interferometer to radio uses. This device, using two dishes separated by a baseline, can achieve far better resolution and positional accuracy than a single antenna larger than either of the two. (See "Using Earth as a Radio Telescope" in ASTRONOMY, October 1979.) The baseline can be any convenient length and the individual telescopes need not be very big (5 or 6 meters diameter).

The signal arriving at one antenna is compared with the signal arriving at the second antenna; when their phase difference is zero, the antennas are pointing exactly at the object and simple geometry gives the object's position in the sky.

Very long baseline interferometry has been made possible by the computer — two radio telescopes hundreds or thousands of miles apart observe a given radio source at the same time, recording the data on magnetic tape along with a standard time signal (such as radio station WWV). Later, the signals' phases are compared and analyzed by a computer. Positional resolution of radio sources accurate to 0.1 second of arc (and in special cases, 0.001 second of arc) is possible. Astronomers can then map details in objects which previously appeared only as point sources or broad smears.

If several dish antennas are arranged along a straight line, even better resolution can be obtained. When the array is in the form of a giant "plus" sign on the ground with arms oriented parallel to the four directions (N, E, S, W), it is called a *Mills Cross*. Astronomers have mapped the distribution of neutral hydrogen in the galaxy with several such Mills Cross arrays. A more complex and variable antenna pattern can give better resolution (a technique called aperture synthesis), but the data are more difficult to analyze.

The largest radio interferometer in the world is presently being finished near Magdelena, New Mexico. Called the Very Large Array (VLA), it provides multiple dish antennas of large collecting area which are movable along a Y-shaped cross with a baseline of 35 kilometers. The VLA combines the advantages of big dishes' large collecting area with resolution of aperture synthesis interferometry.

An astrophysicist working on a problem is trying to deduce what kinds of processes are taking place in or around the object he's interested in. Next month, in the conclusion of this two-part article, we'll take a look at today's radio universe and try to peek ahead to see what its future may hold.

Clarence Annett is an Instructor in the University of Kansas Physics Department, and has taught at the Kansas State University planetarium and observatory. His current research interest lies in laboratory simulation of the martian atmosphere. He is also developing a laboratory manual in observational astronomy.

ASTRONOMY IN FOCUS

Sir / We were most interested in the letter from Gerry Russo published in the November 1979 issue, regarding the satellite re-entry that he observed.

We believe the satellite was a French one named "Signe 3." It had the international designation 1977-49A, and was launched into orbit by a Russian rocket, the last stage of which will survive the payload by several months. The launch took place on June 17, 1977, so its orbital lifetime was 735 days, and the satellite was on its 11,317th orbit at the time of re-entry.

Our calculations indicate that it would have been visible from 02:43 to 02:45 UT on June 22, which corresponds to the EDT times quoted. (Observers should always report times giving UT, Universal Time being a system which astronomers and others use for worldwide comparison and reporting of timed events.) Details of the observer's latitude and longitude would have helped immensely in the analysis of the report.

However, we congratulate Mr. Russo on correctly indentifying the type of phenomenon and thereby avoiding an increase in the total of U.F.O. reports! Estimates indicate that around two re-entries occur every day throughout the world and an average of two or three should be visible each year from any one place (disregarding cloud cover, daylight, etc.).

Russell D. Eberst
D. Alan Pickup
Royal Observatory
Edinburgh, Scotland

Sir / One morning several weeks ago, I used a light pollution reduction filter to "split" Antares, and I sent you a letter to the editor describing my experience.

Soon after mailing the letter, I discovered I had made a mistake. My instructor informed me that the double star appearance was due to a refraction effect from the LPR filter, and not the *real* Antares B. Imagine my surprise when I later resolved Altair into two components (one green), 61 Cygni into four components, and the Trapezium into eight stars!

Then, much to my dismay, my letter found its way into your December 1979 In Focus. I am writing this letter to prevent any other amateur astronomers from being misled by the inherent effects of LPR filters.

Barry Rice
Oak Park, IL

Sir / In "The Cosmological Principle" by Paul S. Wesson (ASTRONOMY, October 1979) a statement is made concerning the size of the universe which I am unable, as a novice, to reconcile.

He says that "the universe that we can see is about 40 billion light-years in diameter." If the universe began with the Big Bang and if the age of the universe is generally accepted to be 15 billion years, how could material, traveling at less than the speed of light, expand to a distance more than twice the distance light could have traveled?

Michael H. Levitt
Larchmont, NY

Mr. Levitt / The value of the Hubble Constant, on which the age of the universe depends, remains a very uncertain figure. As a result, estimates of the universe's age vary from under 10 billion years to 20 billion years, though most astronomers would opt for a value between 15 and 20 billion years. Assuming the largest value of 20 billion, the most distant material we could theoretically detect would be 20 billion light-years away (see "The Cooling Fire of Creation" in this issue). This implies an observable universe with a radius of 20 billion light-years, and therefore a diameter twice that radius: 40 billion light-years.

Sir / Out of all the magazines I receive every month, ASTRONOMY is my favorite. I really enjoy Stellar Frontiers, Forum, and the very first story. Reading Photography in Astronomy, my astrophotography has improved. Sky Almanac is useful because I like to know what's going on with the Moon, planets, and meteors. The extra pages in November's (1979) issue are perfect. Stars and constellations are my favorite part of astronomy, so I would like to congratulate Dewey Schwartzenburg and James Mullaney for doing a superb job in Star Dome.

ASTRONOMY has everything I want in a magazine and every issue is getting better and better as time goes by. This magazine is so clear that a 13 year old like myself can understand every word in it. To all the staff at ASTRONOMY, do not make this old saying come true: "All good things must come to an end," because you would have 1/10 of a million unhappy readers!

Wendell Shuster
Coquitlam, BC
Canada

Sir / I find the commotion over the SPS (Solar Power Satellites) rather interesting. While I am not in the position to judge the merits or demerits of the SPS, I take issue with some facets of the arguments presented by Messrs. Baudino and McGuire (In Focus, November 1979).

G. Baudino's argument seems to be just so much *ad hominem* rhetoric; therefore, I feel I can safely discount it.

M. McGuire, however, presents some intriguing points. One point suggests that we, the United States, may not "want" the SPS. I suggest that the U.S. at the present time is in a position such that our wants must not take precedence over our needs. Mr. McGuire opines that we do not need the SPS; I'm not so sure. In order to maintain our position as a world power (like it or not, we are one), we may need eventually to consider using the SPS as a power source in the same manner that we are considering using fusion and solar power.

If we disregard the importance of maintaining our position as a world power, we should keep in mind that by ignoring our role, geopolitical disruptions could result with unfavorable consequences.

Mr. McGuire also states that the U.S. "has a ravenous appetite for energy." Superpowers usually do. I believe Freeman Dyson worked out a "yardstick" for interstellar civilizations whereby their advancement is coincident with a necessary consumption of energy — the higher the level of civilization, the greater the need for energy. Such a "yardstick" could perhaps also be used for lesser planetary powers.

Finally, Mr. McGuire addresses what he feels is the "apparently unbounded faith in the power of technology and the omnipotence of men" of those who disagree with Mr. Halvorsen by saying a few things about people corrupting the universe. Does he mean to say that all those who disagree with Mr. Halvorsen are intent upon corrupting the universe? How do you corrupt a universe by building an SPS? And what of those "techno-messianic zealots" of Mr. Baudino who desire to plunder and rape a universe by building a few SPSs around an insignificant planet of an ordinary star of an average galaxy? The opinions Messrs. Baudino and McGuire have of those criticizing Mr. Halvorsen's position on the SPS border on the absurd. We may, in the end, decide not to use the SPS, but such a decision should be made only after significant and methodical deliberations.

Overall, Mr. McGuire seems to be employing the "Think Small" mentality when the "Big Idea" is called for. Mr. McGuire furthermore states that he is a romantic; perhaps he should step out from the roseate fog of romanticism into the light of reality, painful as it is, when considering issues upon which our future as a civilization rests.

David J. Ulrich
Marshall, MN

Ooops!

Gazer's Gazette for January contains an editorial error on page 42: All the times listed are 2 hours late. In the upper part, if you subtract 2 hours from the times given, you'll get the central meridians as shown. In the lower table you can do this, or use the time given (10:30) and add 29° to the central meridians listed. Our apologies!

behind the scenes

ATTENTION: astronomy clubs

We often get letters asking if ASTRONOMY offers special group subscription rates to astronomy clubs or other groups. The answer is: "Yes, we do." In fact, we offer two special rates on ASTRONOMY.

First, we'll give members of your club or organization 33% off the individual subscription price, if your club secretary handles collecting and renewing subscriptions with club dues and sends us a single check each year. The Kansas Observers, an astronomy club in Wichita, offers ASTRONOMY, as do the Santa Barbara Astronomy Club and the URSA Astronomy Association of Helsinki, Finland. We won't impose stringent conditions (such as requiring every member of your club to subscribe) in order to qualify your group for discount rates. Ask us about it. The group subscription contact at ASTRONOMY is Stephanie Kiel.

Of course, astronomy clubs are not the only organizations with members interested in the stars. For example, the Science Museum of Minnesota, located in Saint Paul, offers a discount to ASTRONOMY to every museum member. If your group is interested, write for more information.

Second, we sell ASTRONOMY through planetaria, telescope dealers, science stores, hobby shops, camera dealers, and other specialized outlets all over the world. Right close to home, Desforges Booksellers on Wisconsin Avenue now sells ASTRONOMY. You can also pick up a copy of ASTRONOMY at Armagh Planetarium in Northern Ireland, at the next meeting of the Hong Kong Amateur Astronomical Association, the Hinky-Dinky Superette in Bozeman, Montana, or the bookstore at Sir Wilfrid Laurier University in Waterloo, Ontario.

These outlets purchase the magazines at a discount and sell copies at the cover price to visitors and customers. If you operate a shop that could sell ASTRONOMY, or know of a business that *ought* to sell ASTRONOMY over the counter, we invite your inquiry. Our bulk copy sales contact is Nancy Faustmann.

Finally, if you happen to be a confirmed newsstand buyer, ASTRONOMY is distributed nationwide to newsstands by Eastern News Distributors, Inc. (Their address is: 111 Eighth Avenue, New York, NY 10011.) You'll find ASTRONOMY sold in Grand Central Terminal in New York and the Harvard Square Kiosk in Cambridge, to name just two of the 900+ that carry ASTRONOMY. If it's not on your local newsstand, ask your news dealer to contact Eastern about taking on ASTRONOMY.

We'd like to see ASTRONOMY on more newsstands. We know that many of our current readers (about one in every twelve, in fact) might not have known ASTRONOMY exists if they hadn't happened to see a copy sitting enticingly between *OMNI* and *Scientific American*, bought it, read it, and liked it.

Now for a complete change of subject. We've had a lot of requests for posters of the "Night Face of North America," which ran on pages 20 and 21 of the January 1980 issue, and the newest "Saturn by Pioneer" in February's AstroNews. So we've made them into 15" x 19" posters on 17" x 22" stock, rolled and mailed in a strong tube, for **$2.95** each. (You can order them through our bind-in order form.) I think these are real prize winners.

Sincerely,

Richard Berry

Richard Berry

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Celestron International	88
Coast Navigation School	77
Coulter Optical	38
Criterion Mfg.	86
E&W Optical	74
Edmund Scientific Co.	76
Gorman, Paul	76
Hansen Planetarium	78
Hirsch, Edwin	74
Holt, Rinehart & Winston	29,52
Hoosier Telescope	76
Kansas, University of	78
Library of Science	79
Luft, Herbert	76
Main Camera	76
Meade Instruments	44-45
Meyers, B.E.	77
Optica b/c	77
Optron Systems	75
Orion Telescope Center	27
Pentax Corp.	87
Questar Corp.	3
Rocky Mountain Science	66
S&S Optika	25
Sky Scientific	75
Texas Nautical Repair	74
Tuthill, Roger	36,37
Venable, Thomas	77
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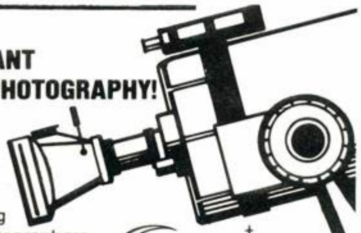

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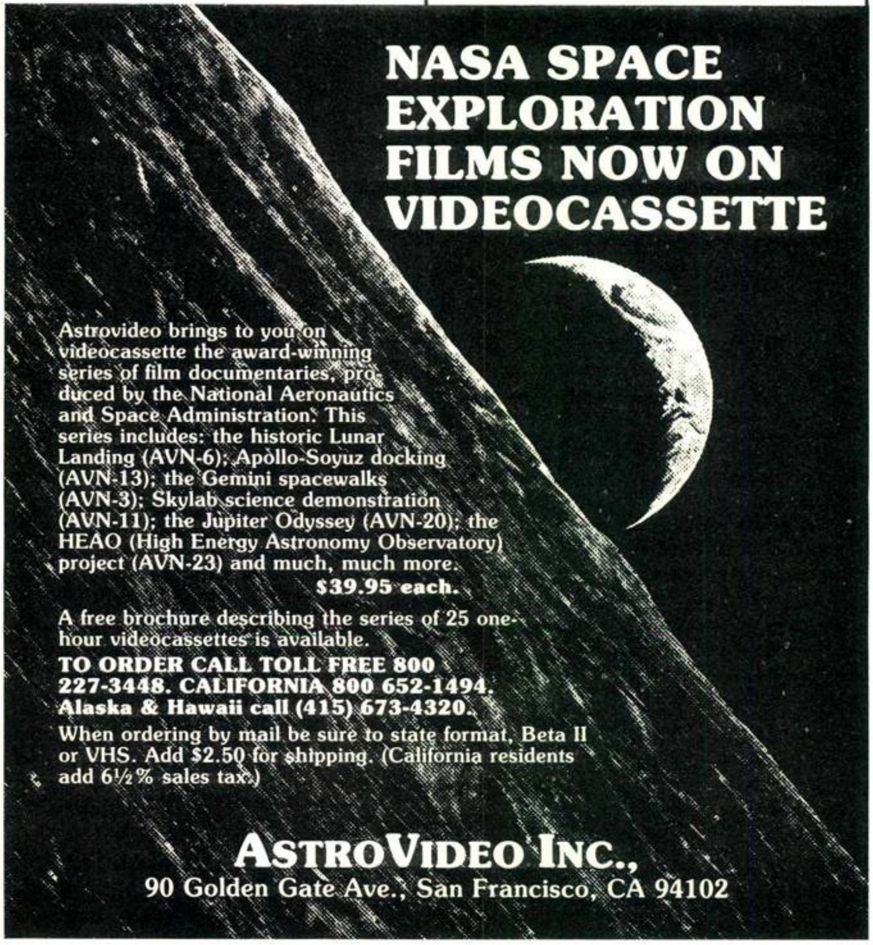

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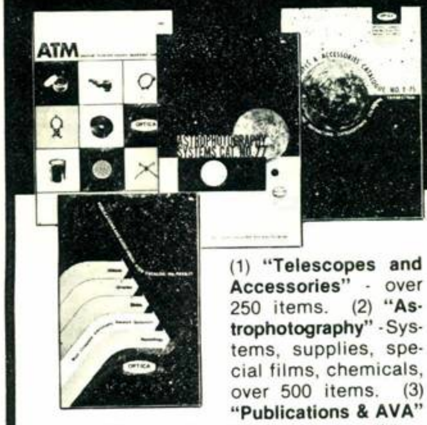

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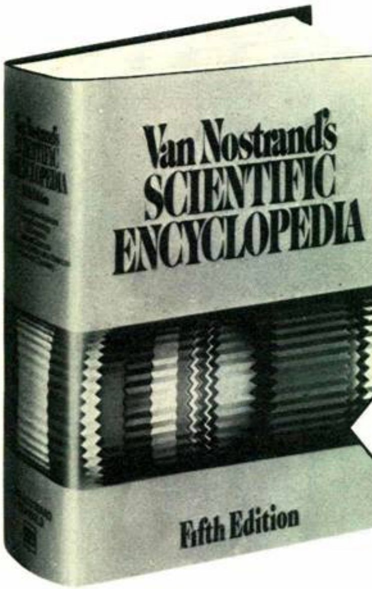

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march: close-up on western hydra/antlia/pyxis

by Dewey Schwartzenburg & James Mullaney

The proverbial line that the month of March "comes in like a lion and goes out like a lamb" undoubtedly refers to the weather of this month, which lies on the border of winter and spring. We can't help but wonder, though, if there isn't a reference to the heavens in the traditional saying, for March evenings bring Leo the lion high into the sky overhead, while Aries the ram (O.K., not quite the same as a lamb!) "goes out" by sinking below the western horizon.

But a more fearsome beast than a lion rises into the evening sky after sunset on March nights. This is the constellation Hydra, the water dragon, and as the night wears on, more and more of its immense length coils and slithers above the southeastern horizon until we wonder when we will finally reach its tail. Hydra is not only the largest constellation, but by far the longest. It extends from 8 hours right ascension to 15 hours — nearly a third of the way around the sky — bordering both Canis Minor in the winter sky and Libra in the summer heavens.

At midnight on the spring equinox, the immense dragon Hydra stretches its full length across the southern sky. Indeed, it may have been this fact which helped to form the creation epic of ancient Babylon, recited each year at the New Year's Festival observed on the spring equinox.

According to the Babylonian myth, the god Marduk created the world out of the body of the sea-dragon Tiamat, whom he killed in a great battle. By this feat Marduk, who was only one of many gods, became the king of the gods, and from the blood of another dragon named Kingu — which he slew — created the human race.

At the time of the recital of this myth in March, the great dragon Hydra could be seen across the night sky, finally disappearing below the western horizon as the Sun rose in Aries, inaugurating the new year. The King of Babylon, who represented the god Marduk, would ascend the seven-leveled pyramid — known as the Great Ziggurat of Marduk — at dawn to celebrate the beginning of the year by re-enacting Marduk's exploits.

Marduk, by the way, is often identified as the spirit of the planet Jupiter, and the ancient Babylonians said that he had four eyes. Could they have known of the four large satellites of Jupiter, which would be (barely) visible to the naked eye if it were not for the glare of brilliant Jupiter? Surely knowledge of these four tiny beacons swinging back and forth across the face of Jupiter in everchanging patterns would have suggested to the ancient Babylonians the all-surveying gaze of an omniscient four-eyed god. Certainly the Babylonians had extensive astronomical knowledge, but that they knew of the Galilean satellites is far from proven by this probably coincidental association.

The concept that the world itself is the body of a dragon is not unique with the Babylonians. The Milky Way, which completely encircles the Earth, has been seen in many cultures as a giant world-encircling dragon. The Norse referred to the Milky Way as the "Worm of Middle Earth," and the ancient Akkadians called it the "Snake River." In some Indian myths it is known as the "Path of the Snake." But to the ancient Druids the Milky Way was neither the abode of a dragon nor a dragon itself, but a glass dragon egg made from the eyes of a number of dragons. According to the Druids, this egg, which is the Egg of Time, is created anew each year at the spring equinox in March.

Dragons are not usually seen in such grand, cosmic terms in the classic western myths, where instead they are dreadful monsters overcome by human heroes. One such dragon played an extremely important, though unwilling, part in the founding of the ancient Greek city of Thebes.

When Zeus, disguised as a bull, carried off Europa, her brothers dutifully set out to find her. One brother, whose name was Cadmus, was especially persistent, but no more successful than his brothers. Finally he decided to seek out the oracle at Delphi for advice. The oracle, knowing full well what had happened to Europa and that it wasn't wise to try and get her back from so important a personage as Zeus, counseled Cadmus to busy himself with something a little more fruitful, like, maybe, founding a city.

"O.K.," we can suppose Cadmus replying, "but just where should I found this city?"

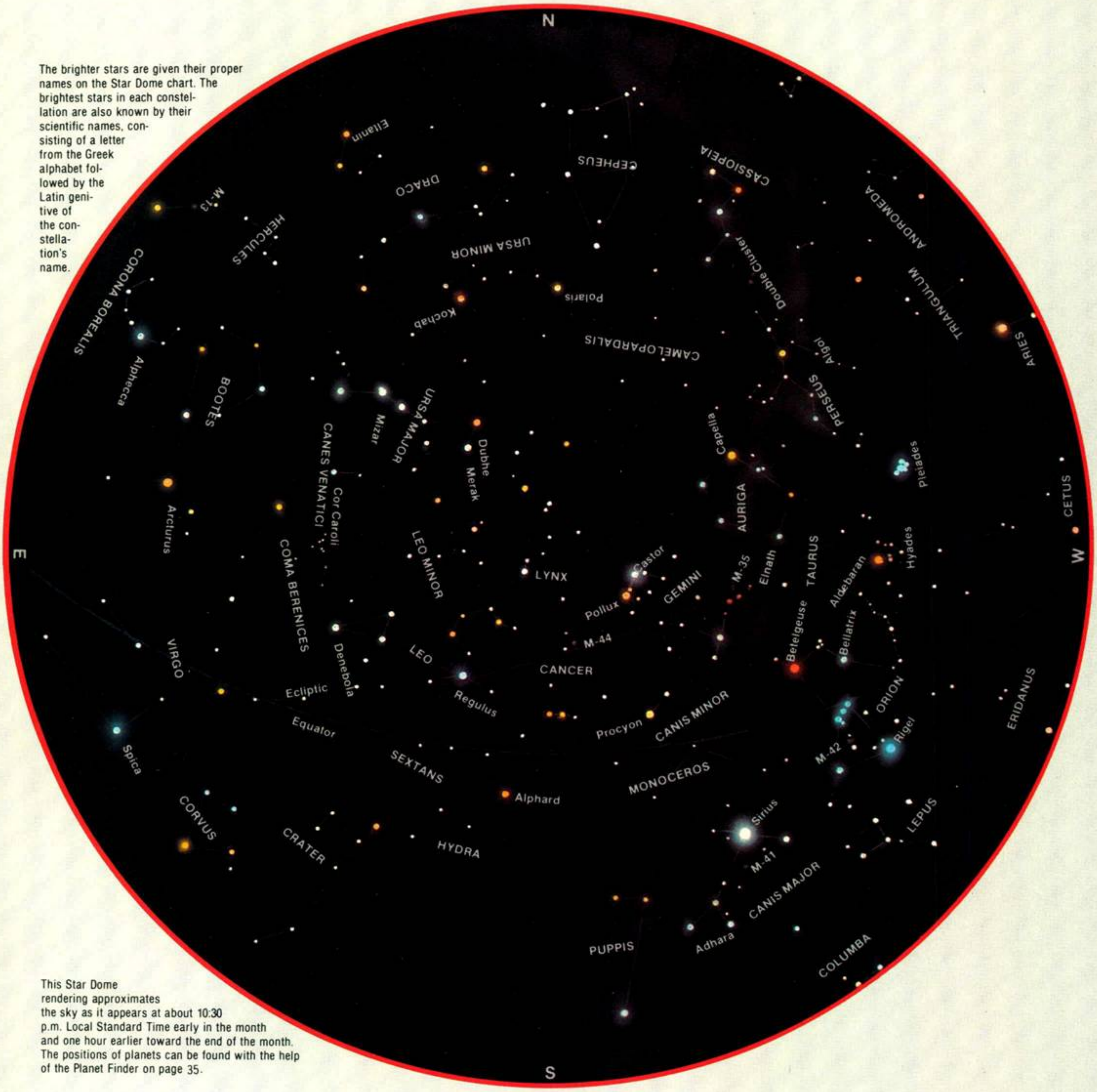
The oracle, presumably knowing no more than a cow where a city should be founded on the basis of trade, strategy, and geography, gave Cadmus what may have been a sarcastic answer: "Go find a cow and follow her until she lies down, and then build your city there!"

Cadmus, apparently lacking a sense of humor, took the oracle literally. Buying a nice-looking cow with attractive markings that looked like full moons on her sides, he proceeded to chase her about the countryside until the poor thing, exhausted, flopped down in a heap.

But the cow's troubles were far from over, because Cadmus, having decided that the cow must be sacred to the moon goddess Athena on account of those nice full moons she had on her flanks, told his companions that the cow obviously had to be sacrificed to Athena as soon as possible. If this were not done, Cadmus was sure he and his new city would earn the goddess's enmity forever — and besides, the cow had done her duty, and found a particularly nice lot with drainage and a good view.

But unfortunately it's difficult — especially when founding a city — to

The brighter stars are given their proper names on the Star Dome chart. The brightest stars in each constellation are also known by their scientific names, consisting of a letter from the Greek alphabet followed by the Latin genitive of the constellation's name.


N
S
E
W
Eltanin
CEPHEUS
CASSIOPEIA
M-13
DRACO
HERCULES
URSA MINOR
ANDROMEDA
Double Cluster
CORONA BOREALIS
Polaris
Kochab
TRIANGULUM
CAMELOPARDALIS
Algol
ARIES
Alphecca
BOOTES
Mizar
URSA MAJOR
PERSEUS
CANES VENATICI
Cor Caroli
Dubhe
Merak
Capella
Pleiades
CETUS
Arcturus
COMA BERENICES
LEO MINOR
AURIGA
Elnath
TAURUS
Hyades
LYNX
Castor
M-35
Aldebaran
GEMINI
Pollux
Betelgeuse
Bellatrix
VIRGO
Denebola
M-44
CANCER
LEO
ORION
ERIDANUS
Ecliptic
Regulus
Equator
Procyon
CANIS MINOR
Rigel
M-42
Spica
SEXTANS
MONOCEROS
Alphard
CORVUS
Sirius
LEPUS
CRATER
HYDRA
M-41
CANIS MAJOR
Adhara
PUPPIS
COLUMBA

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month and one hour earlier toward the end of the month. The positions of planets can be found with the help of the Planet Finder on page 35.

avoid angering one or another of the gods, and Cadmus managed to get himself on the bad side of a rather important one: Ares, the god of war. For when Cadmus, knowing that you couldn't perform a proper sacrifice without lots of lustral water to scatter around, sent his companions to fetch some water from a nearby spring, he didn't know that the spring was sacred to Ares, who had placed a nasty dragon there to guard it. The dragon killed most of Cadmus's men, and so Cadmus came himself and dispatched the serpent by hitting it on the head with a rock. Ares, of course, was furious.

Cadmus got his water, though, and the cow came to an untimely end. It turned out that Athena was quite pleased by the sacrifice, so she repaid Cadmus by telling him to get the teeth of the dragon he had slain and sow them in the ground. It seems that this particular dragon, although relatively easy to kill, had quite magical teeth which when sown immediately sprang up as armed men, roaring, clashing their weapons, and obviously ready to cause trouble.

Finding himself suddenly surrounded by scores of savage soldiers and probably wondering if Athena was much of a friend after all, Cadmus tried to distract them by tossing a rock into their midst, whereupon the pugnacious throng fell to brawling among themselves over who threw it.

The five fiercest survived the melee, and seemingly not very intelligent, immediately offered their service and allegiance to the one who had started the whole fight, namely Cadmus. So Cadmus came out of the affair quite well after all, and realized that Athena was only trying to help by replacing the men he had lost to the dragon.

These five warriors became the ancestors of the Thebans, the inhabitants of the city Cadmus founded, who were known in later times for their fierce and warlike spirit. But Ares got back at Cadmus for having slain his pet dragon by imprisoning him for eight years, so

there was a little delay in getting things organized in Thebes. History does not record whether or not the Thebans, in addition to being belligerent, were also prone to procrastination.

But that's not the end of the dragon's teeth, for they reappear in another quite different story. This is the story of Jason and the Argonauts, which served rather as a soap opera for the ancient Greeks, so endless are the twists in the tale and the variant forms recorded.

All the different versions, though, are pretty much in agreement concerning the acquisition of the Golden Fleece, Jason's major accomplishment. Aetes, who as we saw last month was the King of Colchis who had hidden the Fleece in a cave and set a dragon to guard it, agreed to let Jason have the Fleece if he could perform a rather difficult task. He had to yoke two fire-breathing bulls, plow a field, and sow it with some of Cadmus's leftover dragon's teeth.

With the help of Medea, the daughter of the King, Jason managed to perform this task, and when the expected armed men sprang up, Jason — who knew his mythology — dealt with them as Cadmus had by tossing a stone into the mob. Apparently none of the warriors survived the ensuing brawl, except for a few wounded to whom Jason rather cruelly administered a *coup de grace*.

It is unfortunate that none survived, for Jason could have used their assistance against Aetes, who reneged on his bargain and refused to give up the Fleece. It turned out that Aetes had never expected Jason to be able to perform the task he had set him anyway. But, as we related last month, Medea had fallen in love with Jason and so turned against her father to aid Jason with her witchcraft. She ultimately ran off with him, and committed all sorts of more or less loathsome crimes both for his benefit and, on occasion, against him.

So the rest of their story grows more and more sordid and complex until the tale of Jason and Medea begins to resemble an ancient version of "Who's Afraid of Virginia Woolf?" Undoubted-

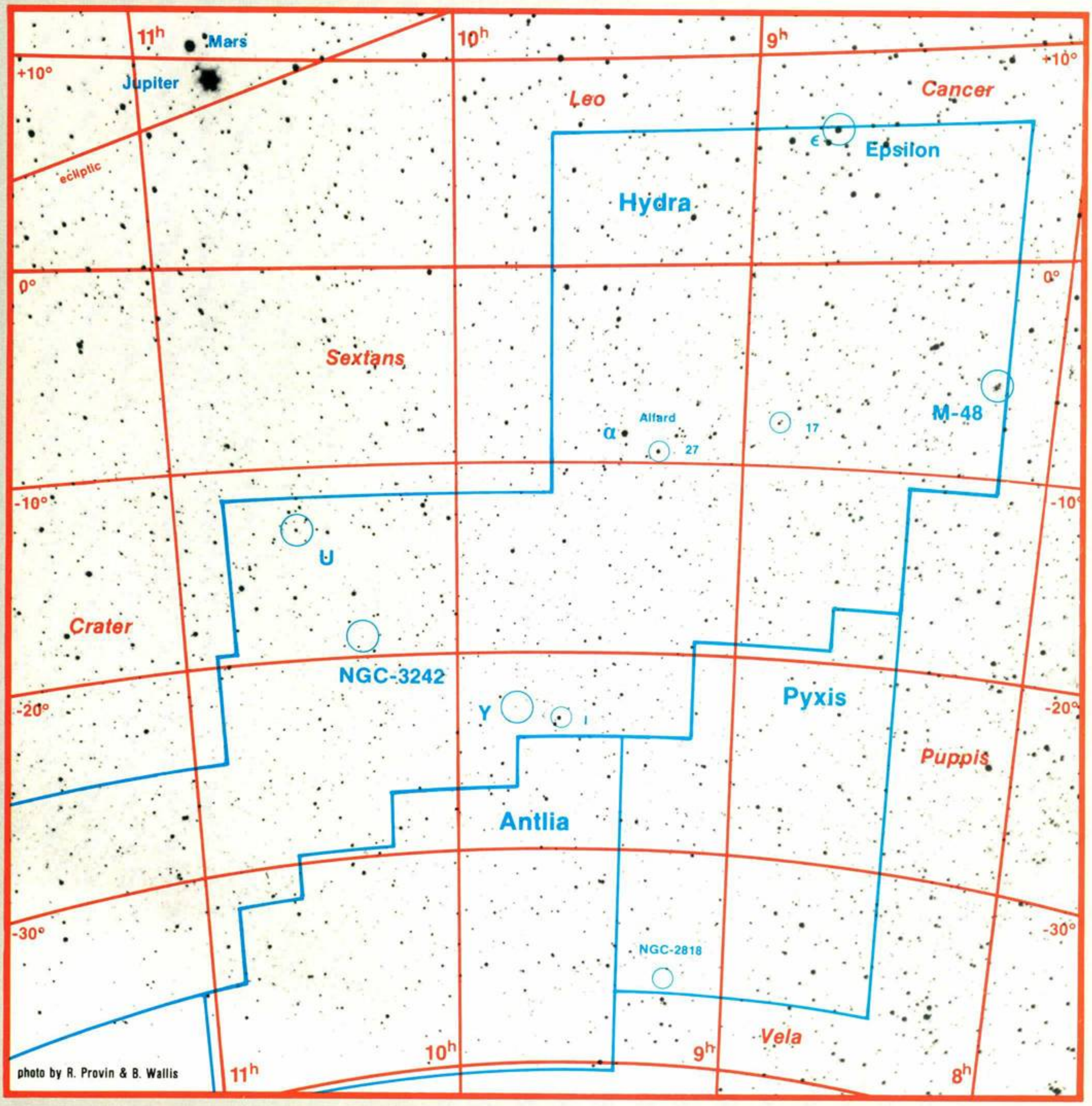


photo by R. Provin & B. Wallis

ly it was regarded as unfit for children and sold only under the counter in ancient cities, which may account for the number of different versions which have come down to us. Suffice it here to say that the two heroes of this particular tale did not live happily ever after!

close-up

Western Hydra/ Antlia/Pyxis

Of the great celestial dragon Hydra, Barns wrote: "The limited pentagonal area (of Hydra's head)...is quite the most compelling section of the mythical monster which drags its dull length from this point south and eastward nearly a third the distance around the celestial sphere. It would be strange indeed if so vast a precinct were not relieved here and there with some veritable highlights, available in our latitudes with fine seeing."

For its extensive size, the water dragon is poorly stocked with subjects and is also one of the more obscure celestial figures. This month's survey includes the area of sky from Hydra's head as far east and south as the border of Crater, together with the two constellations immediately south, Antlia and Pyxis.

To the unaided eye, Hydra's most prominent feature is its rhomboidal-shaped head. Olcott referred to this figure as a "striking and beautiful group of stars." Barns elaborated on the scene: "Zeta, Epsilon, Rho, Delta, Sigma, and Eta Hydrae, in same field, with lesser lights, present a brilliant pageant." A look here with wide-angle binoculars will quickly show what all the talk is about. Another naked-eye highlight of Hydra is Alphard [Alpha (α) Hydrae], southeast of the head. This second magnitude reddish-orange star is known as the heart of the dragon.

This month's region also includes two adjoining and equally obscure constellations — Antlia (the air pump) and Pyxis (the mariner's compass), both lying just south of western Hydra.

Antlia, named in honor of Robert Boyle's eighteenth century invention, is a singularly dim constellation, having only one star brighter than fifth magnitude — and that barely: Alpha (α) Antliae shines at only 4.46. Even Antlia's one claim to fame, the spectacular planetary nebula NGC-3132, is the subject of a "border dispute" with neighboring Vela and is sometimes listed as being in that constellation instead.

Pyxis, another relatively "modern" constellation only distinguished and named as such within the past couple of centuries, was originally part of the giant constellation Argo, the ship. Placing a compass on Jason's ancient ship, of course, is quite an anachronism, and this region originally was merely part of the mast of the Argo. Although the brightest star, Alpha (α) Pyxidis, is second magnitude, all the other stars in this small constellation are fourth magnitude or fainter.

Despite the barren aspect of this month's region, it does contain some delightful telescopic surprises, to which we now turn our attention.

M-48

At the extreme western boundary of Hydra resides a cosmic personality that was considered "lost" for years, but turned up "alive and well" a few years ago. This is the open cluster M-48, located about three degrees southeast of fourth magnitude Zeta (ζ) Monocerotis.

For years this object was regarded as one of the missing entries in the Messier catalog, but it has now been convincingly identified as NGC-2548 by Harvard astronomer and historian Owen Gingerich. The cluster's right ascension is essentially that given by Messier, but its declination is exactly five degrees south of his value. Messier apparently made an error in recording his discovery position.

M-48 is just visible to the unaided eye on a dark transparent night, but it's not easy to locate with a telescope due to the lack of any nearby guide stars. However, careful sweeping with your finder will pick it up.

This cluster contains some 80 stars in an area the size of the full moon (30 minutes), and together these shine with the luster of a 5.3 magnitude star. It is fairly rich for an open cluster, and a fine sight in four to eight-inch telescopes at low power.

Webb listed this object under neighboring Monoceros as NGC-2548, describing it as a "group of pretty uniform ninth magnitude stars, with a profusion of lesser ones."

This "misplaced" swarm of suns glistens at us from across 3500 light-years of interstellar space.

Epsilon (ϵ) Hydrae

The star at the very top of Hydra's head, flanked by the stars Zeta (ζ) and Delta (δ), is a good starting point for our telescopic exploration of this region's wonders. This is the complex binary system Epsilon (ϵ) Hydrae.

Here we encounter 3.5 and 6.9 magnitude suns a close three seconds of arc apart. A color contrast is evident — nearly all observers call the stars yellow and blue in tint. Smyth said they were pale yellow and purple, while Webb (in 1851) saw the companion as ruddy.

The two stars are in slow orbital motion about each other with an uncertain period given as 900 years. This motion resulted in small but noticeable changes in the pair's separation and position angle over the years. In 1929, for example, these values were 3.6 seconds and 253 degrees, respectively. At present they are about 2.8 seconds and 280 degrees.

A three-inch refractor at high power can resolve this duo on a steady night, but larger instruments are needed to really appreciate Epsilon's appeal.

Good seeing (image steadiness) is extremely important in looking at Epsilon, which probably accounts for the fact that William Herschel missed this pair during his long, intense sweeps of the heavens. His observing sites in England were frequently plagued by clouds and turbulent air — yet he pushed on to see and discover more than any observer who came before or after him. This should be a source of inspiration to all who love stargazing but are plagued by poor conditions. At least Herschel didn't have to contend with city lights or a neighbor's blazing barbecue!

U and Y Hydrae

We come now to two vivid red variable stars well worth a look by those who enjoy celestial colors. The first of these is U Hydrae, which forms the top of an equilateral triangle with third magnitude Nu (ν) and fourth magnitude Mu (μ) in the body of the dragon. This star is an irregular variable of uncertain period, and ranges from 4.8 to 5.8 magnitude — easily within reach of finders and binoculars.

The other red cosmic eye is designated Y Hydrae. It can be found two degrees east and slightly north of the fourth magnitude double star I Hydrae (see our table of selected objects). This pulsating sun is classified as semiregular and has a period of 303 days. Like U Hydrae, it varies by a full magnitude — this time from 6.9 to 7.9.

Both of these objects are of the rare spectral class N and through the telescope have a striking deep red cast. Although listed without comment or omitted entirely from most observing references, they present stunning sights, especially on dark nights. On nights of high transparency with accompanying poor seeing, these two southerly red stars may take on the appearance of flashing buoys riding the serene ocean of night.

Deeply tinted orange and red stars are missing from the observing diet of most deep-sky watchers today, but back in Webb's time they received special attention. Indeed, observers like Espin and Birmingham in England conducted extensive surveys of the sky looking for just such objects.

Most of these celestial spotlights are long period variable stars; in selecting them as telescopic showpieces for visitors, it is important to find ones with fairly limited magnitude ranges. You'll want to make sure they'll be visible when you show them to others, as many vivid red stars will drop below your scope's limit at the minimum

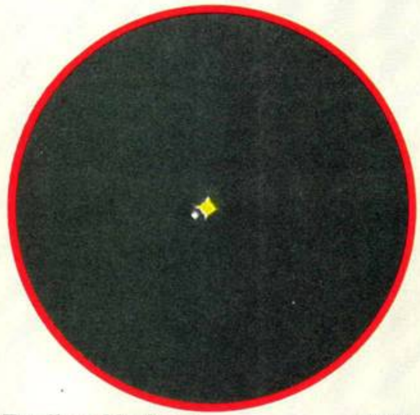
Selected Objects — Western Hydra/Antlia/Pyxis

Object	Type	Mag.	Size/Sep. Per.	R.A.	(1950) Dec.
*M-48	○	5.3	30′	08^{h}11^m	−05°38′
*Epsilon (ϵ) Hya	★^{2}	3.5,6.9	3″	08^{h}44^m	+06°36′
17 Hya	★^{2}	6.7,6.9	4″	08^{h}53^m	−07°47′
NGC-2818	○	9.8	9′	09^{h}14^m	−36°24′
27 Hya	★^{3}	5.0,6.9,9.0	229″,10″	09^{h}18^m	−09°21′
I Hya	★^{2}	4.8,8.1	54″	09^{h}39^m	−23°22′
*Y Hya	m★	6.9-7.9	303^d	09^{h}49^m	−22°47′
*NGC-3132	■	8.2	84″x53″	10^{h}05^m	−40°11′
*NGC-3242	■	9	40″x35″	10^{h}22^m	−18°23′
*U Hya	∩★	4.8-5.8		10^{h}35^m	−13°07′

★	*Star*	m★	*Regular Variable*	●	*Globular Cluster*	§S	*Spiral Galaxy*
★+	*Bright Star*	∩★	*Irregular Variable*	■	*Planetary Nebula*	§ʃ	*Barred Spiral Galaxy*
★^{2}	*Double Star*	ⲏ★	*Eclipsing Variable*	□	*Bright Diffuse Nebula*	§#	*Peculiar Irregular Galaxy*
★^{3}	*Triple Star*	○	*Open Cluster*	§0	*Elliptical Galaxy*		

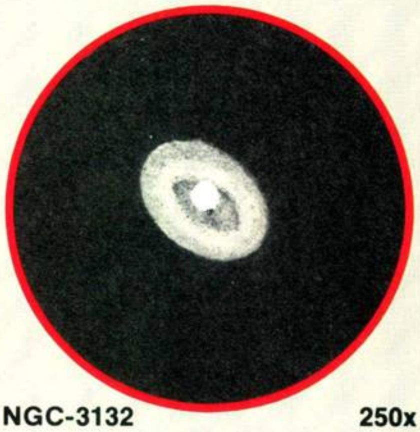
phase of their light cycles.

M-48 **60x**

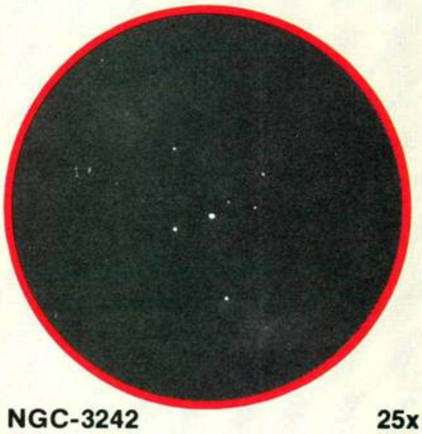


Epsilon Hydrae **250x**

M-48, though difficult to locate, is a fairly rich and large open cluster requiring a wide field of view. Photo by Jack Newton. Epsilon Hydrae is a lovely contrasting yellow/blue double star. Separated by only three seconds of arc, this impressive double must be seen in fairly large telescopes for the colors to stand out clearly. Drawing by James Mullaney. NGC-3132, one of the most superb planetary nebulae in the sky, is also known as the Eight-Burst Nebula. Drawing by Tom Reiland. NGC-3242 is a large, distinctly blue planetary nebula, easily visible through even a 2.4-inch refractor (as this drawing shows). Drawing by James Mullaney.



NGC-3132 **250x**



NGC-3242 **25x**

NGC-3132

Because most planetaries — like most clusters and diffuse nebulae — are located along the Milky Way, there are fewer visible during the spring than in any other season. One that is definitely worth the search is NGC-3132 in Antlia (or maybe Vela, which is where Robert Burnham, Jr. places it). NGC-3132 is a ring nebula that surpasses M-57 in detail and brightness. Nicknamed the Eight-Burst from the complex structure apparent on photographs, NGC-3132 is a soft, blue-white nebula — visually, a more appropriate name might be the Easter Egg Nebula.

Though not well-known (probably because of its far southern declination), NGC-3132 must rank as one of the finest of all planetaries, and as such made ASTRONOMY magazine's list of the "top 21" deep-sky objects (see the October 1979 issue).

This oval or egg-shaped object surrounds a bright, prominent 10th magnitude central star. The presence of a bright central star is unusual in planetary nebulae, but observers should be warned that this star is not in fact the star responsible for the neonlike glowing of the nebula itself. That honor goes to its invisible companion, a sixteenth magnitude dwarf star with an exceedingly high surface temperature.

Locating NGC-3132 will be difficult because of its southern declination and the lack of bright stars in the constellation Antila. Try waiting for Regulus in Leo to reach the meridian, and then direct your telescope 52 degrees south of that star — but first make sure your telescope is very well aligned!

NGC-3242

Just two degrees south of fourth magnitude Mu (μ) Hydrae lurks another of the most vivid and remarkable planetary nebulae in the heavens. This is NGC-3242, sometimes referred to as the "Ghost of Jupiter."

Large (40 by 35 seconds in extent) and bright (ninth magnitude), this celestial blue "egg" is obvious in a three-inch refractor at just 45 power. At such low magnification, most planetaries are indistinguishable from stars.

Having an apparent diameter and shape nearly the same as the planet Jupiter, many of the classic observers of the past have compared the two objects in their descriptions. Olcott tells us "it will be seen like a pale blue disk, like the ghost of Jupiter." Admiral Smyth even goes so far as to say that NGC-3242 "resembles Jupiter in size, equable light, and color." On this last point we have to disagree with the Admiral, for this planetary shines with an intense blue glow.

This high surface brightness allows the use of considerable magnification. Even 75 to 100 power on a four-inch telescope reveals hints of internal detail including a bright nucleus. The view in eight-inch and larger instruments is simply thrilling.

The nucleus itself has had an unusual history and merits careful watching by well-equipped observers. Current catalogs list an 11th magnitude central star. But the famed observer W.H. Pickering, using an 11-inch refractor in Jamaica, recorded that "in 1892...(NGC-3242) had a bright star in its center. This has now (1917) disappeared." Webb's description was written prior to 1892, while Barns observed after 1917, but both observers called attention to the star. Perhaps it vanished and then reappeared. Adding to the enigma is the fact that the present form of the nucleus is that of a bright knot rather than a sharply defined star.

At a distance of some 2000 light-years, the Ghost of Jupiter lies 3000 light-years nearer to us than the Ring Nebula.

In our visits to NGC-3132 and NGC-3242, we hope to dispel something of a myth: that, as a class, planetary nebulae are difficult to observe and cannot be seen unless a fairly large scope is used. True, these objects are generally much smaller in apparent size than other types of deep-sky objects, but many of them can be seen in the smallest of telescopes and at very low powers.

Dozens of these strange and intriguing objects can be picked up in a small instrument by a trained and patient eye. Larger telescopes, such as a six or eight-inch, will reveal each of these to have a "personality" all its own — no two are exactly alike. Surprises abound here as in other fields of observing. A little-known object like NGC-3242 will often rival a superstar like M-57 (the Ring Nebula), and yet will rarely be paid a visit by astronomy enthusiasts. No wonder some observers claim these rejects of cosmic society as all their own.

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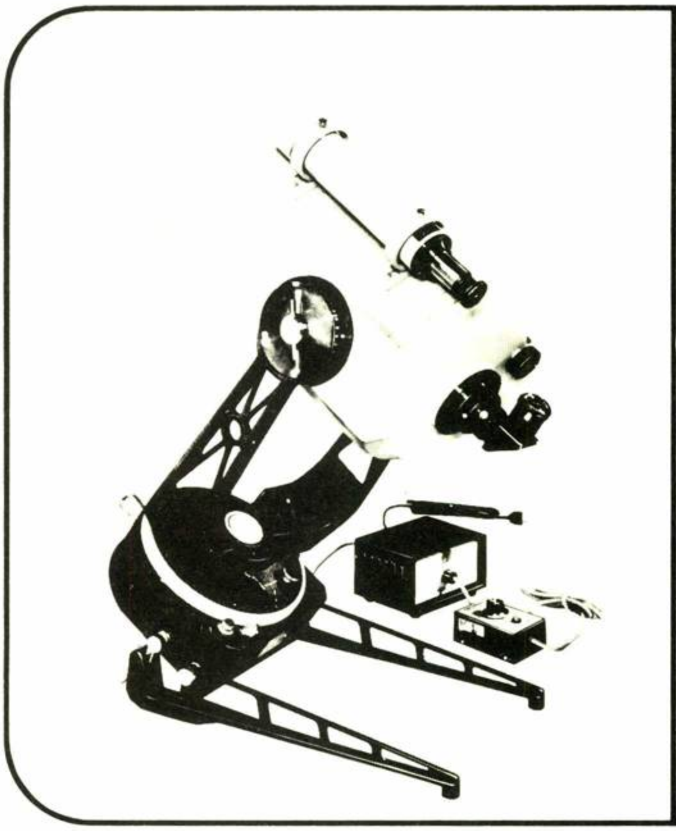

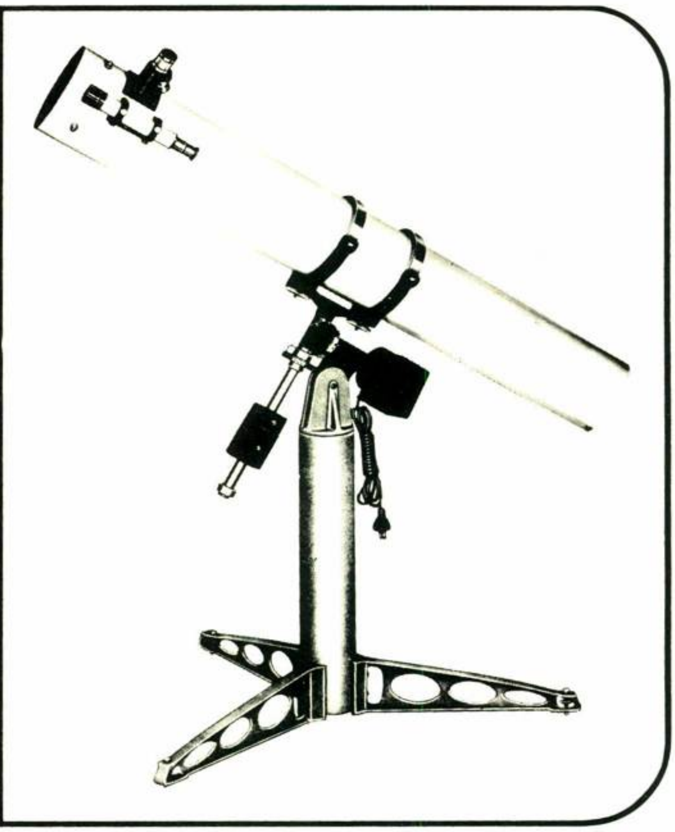

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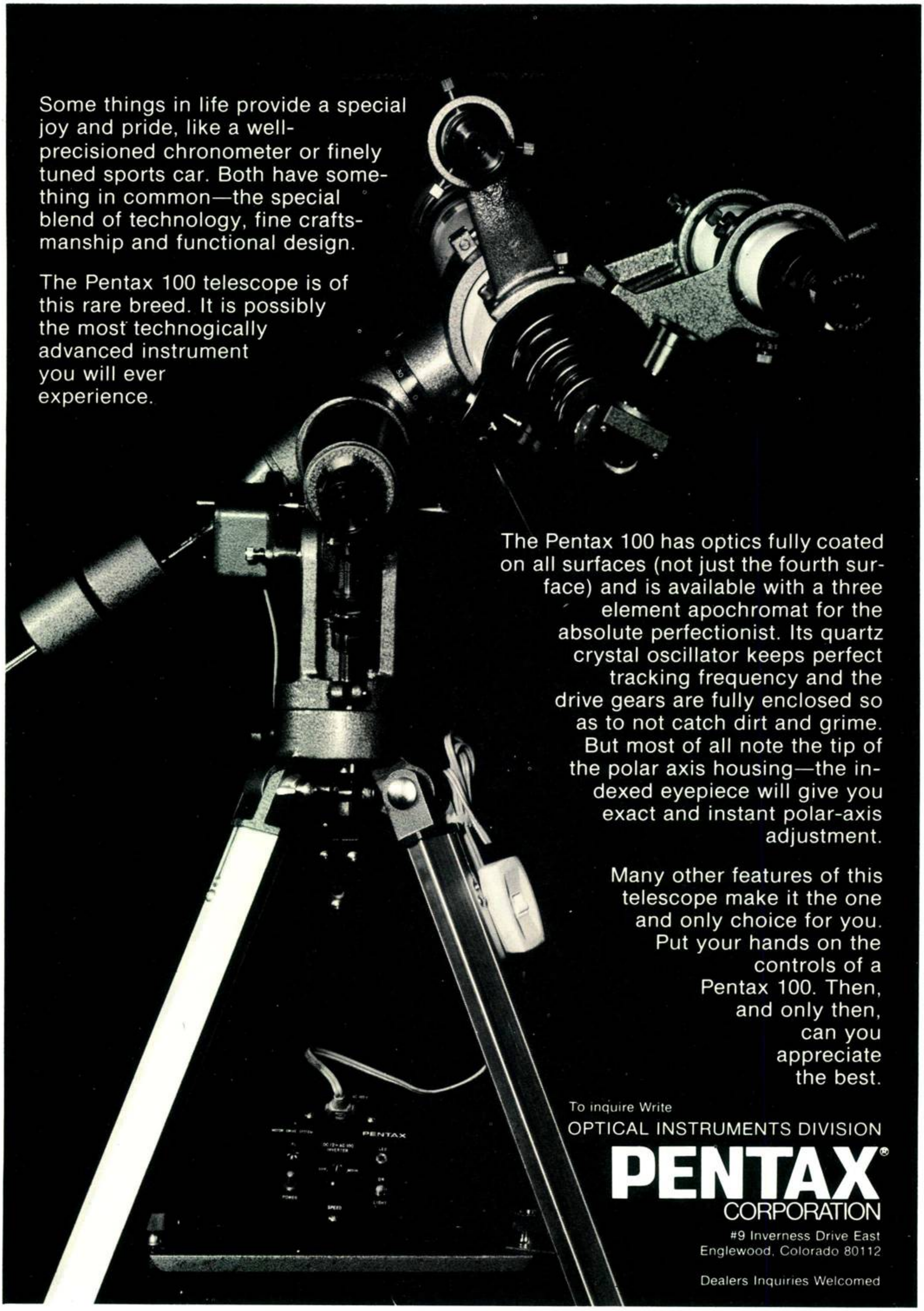

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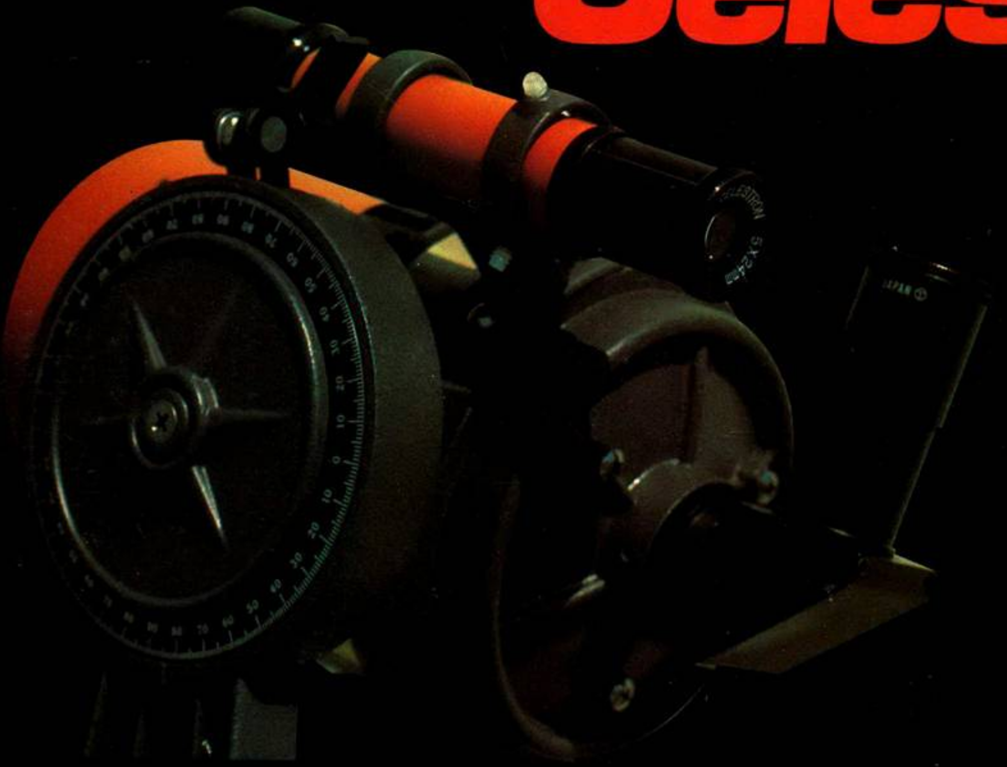

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